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China Report

SCIENCE AND TECHNOLOGY

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CHINA REPORT

SCIENCE AND TECHNOLOGY

CONTENTS

PEOPLE'S REPUBLIC OF CHINA

NATIONAL DEVELOPMENTS

Wang Yuzhao Addresses Anhui Soft Science Meeting
(Anhui Provincial Service, 22 Aug 86) 1

Shanghai Becomes Center for Astronautics Technology
(ZHONGGUO TONGXUN SHE, 10 Sep 86) 3

Technology Imports' Impact on Shanghai Industries Discussed
(RENMIN RIBAO OVERSEAS EDITION, 23 Jul 86) 4

Legal Advice Offered to S&T Personnel in Shanghai
(RENMIN RIBAO OVERSEAS EDITION, 23 Jul 86) 6

Development of Shanghai's Consulting Industry Discussed
(KEXUEXUE YU KEXUE JISHU GUANLI, No 7, 12 Jul 86) 7

Benefits of Hosting International Conferences Discussed
(Chen Zujia; RENMIN RIBAO, 3 Jun 86) 15

Bioengineering Prospects Examined
(Wang Zhen; HUAXUE SHIJIE, No 5, 25 May 86) 17

Bohai Bay Economic, Technical Development Zone Discussed
(Yang Haitian; KEXUEXUE YU KEXUE JISHU GUANLI, No 6, Jun 86) 23

Small Enterprises Urged To Purchase Technology Prudently
(JISHU SHICHANG BAO, 1 Jul 86) 27

Forms of Payment for Commercial Technology Discussed
(Kong Huimin; JISHU SHICHANG BAO, 1 Jul 86) 29

Liaoning People's Congress Plenum Hears Report on Science Policy
(Liaoning Provincial Service, 19 Sep 86) 32

Reform of Science, Technology Commissions Discussed
(Ren Zhenjiang, et al.; KEXUEXUE YU KEXUE JISHU GUANLI, No 7, 12 Jul 86) 33

Summary of 2d International S&T Policy Symposium
(Xu Chaoqian; KEXUEXUE YU KEXUE JISHU GUANLI, No 6, Jun 86) 38

Pilot New Technology Development Zone Operations
(Gu Wenxing, Zhou Liangyi; KEXUEXUE YU KEXUE JISHU GUANLI, No 6, Jun 86) 41

Research Zones in Intellectually Rich Areas Discussed
(Zhao Wenyuan, Li Tieru; KEXUEXUE YU KEXUE JISHU GUANLI, No 6, Jun 86) 45

PHYSICAL SCIENCES

New Neutron-Induced IR Absorption Peaks in Single Crystal Silicon
(Qi Mingwei, et al.; BANDAOTI XUEBAO, No 3, May 86) 51

2 New Amorphous Semiconductor Multilayered Structures
(Chen Zhiming, et al.; BANDAOTI XUEBAO, No 3, May 86) 55

APPLIED SCIENCES

Investigation of Law of Attitude Control of Flexible Spacecraft
(Wu Yaohua, Xu Shijie; HARBIN GONGYE DAXUE XUEBAO, No 1, Mar 86) 59

Production of Noncaking Potassium Nitrate for Use in Kinescopes
(Xu Ji, et al.; HUAXUE SHIJIE, No 5, 25 May 86) 69

Use of Elastic Composite Material in Nitrogen Fertilizer
(Xie Shangli, et al.; HUAXUE SHIJIE, No 5, 25 May 86) 75

Energy Model of Free-Electron Laser
(Chen Jianwen, et al.; ZHONGGUO JIGUANG, No 7, 20 Jul 86) 82

Detector for Particles of Laser Scanning Transfusion Developed
(Yu Jie; ZHONGGUO JIGUANG, No 2, 20 Feb 86) 95

Nd:Glass Laser Hardening Technique Used for First Time in Instrument Manufacture
(Guo Dahao, et al.; ZHONGGUO JIGUANG, No 2, 20 Feb 86) 96

Theoretical Analysis of Single Frequency He-Ne Lasers
(Li Shangyi, et al.; ZHONGGUO JIGUANG, No 7, 20 Jul 86) 98

Free-Electron Lasers With Traveling Wave Field Wiggler
(Lu Ruizheng, Lei Shizhan; ZHONGGUO JIGUANG, No 7, 20 Jul 86) 106

Briefs

Laser Output Stabilizer 113

SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

Top Nuclear Bomb Expert's Simple Life Praised
(Li Chun, Wang Jinchang; ZHONGGUO XINWEN SHE, 27 Aug 86) 114

ABSTRACTS

ANALYTICAL CHEMISTRY

SEPU [CHINESE JOURNAL OF CHROMATOGRAPHY] No 3, May 86 117

ENGINEERING

GUANGXUE XUEBAO [ACTA OPTICA SINICA] Vol 6, No 1, Jan 86 118

MEDICAL SCIENCES

ZHONGHUA YANKE ZAZHI [CHINESE JOURNAL OF OPHTHALMOLOGY] Vol 22, No 3, 12 May 86 119

ZHONGHUA ER-BI-YANHOUKE ZAZHI [CHINESE JOURNAL OF OTORHINOLARYNGOLOGY] Vol 21, No 2, 10 Jun 86 120

ZHONGHUA FANGSHEXUE ZAZHI [CHINESE JOURNAL OF RADIOLOGY] Vol 20, No 3, 10 Jun 86 121

/9986

NATIONAL DEVELOPMENTS

WANG YUZHAO ADDRESSES ANHUI SOFT SCIENCE MEETING

OW240733 Hefei Anhui Provincial Service in Mandarin 1000 GMT 22 Aug 86

[Text] At a recent provincial seminar on soft science research, Governor Wang Yuzhao underscored the need to submit all important policies to systematic feasibility study and meticulous verification by experts.

The 3-day provincial seminar on soft science research was convened at the request of the provincial Scientific and Technological Commission. The seminar transmitted the guidelines of the national seminar on soft science research; summed up and exchanged experience in Anhui's achievements in soft science research in recent years; discussed how to promote soft science research and render policymaking democratic, scientific, and systematic; and offered some valuable opinions on Anhui's economic and social development.

Governor Wang Yuzhao attended the seminar and addressed the closing session on behalf of the provincial party committee and the provincial government. First, he reviewed Anhui's progress in soft science research. Wang Yuzhao said: Anhui research on soft science began in 1980, one of the provinces engaging in this field earlier than in other parts of China. In recent years, it has conducted feasibility study and arranged consultation and verification for its overall development scheme and the larger economic and social development projects. Notable results have been achieved in some of these undertakings. Many industrial and regional plans already formulated demonstrate the results of soft science research.

In analyzing Anhui's problems and shortcomings in soft science research, Governor Wang Yuzhao stated: Anhui has made considerable progress in soft science research. However, it still has a long way to go before meeting the requirement of democratic and scientific policymaking. In summary, Anhui faces the following three problems:

1. Leaders have difficulty in their thinking and understanding of soft science research.

2. The traditional method of policymaking based on experience and personal will is still very popular.

3. The funds and means available to soft science research institutes and personnel are still far from meeting the requirement of democratic and scientific policymaking.

On promoting democratic and scientific policymaking, Governor Wang Yuzhao concluded emphatically: Leaders at all levels should step up the organizational building of soft science research contingents, improve the quality of researchers, and give as much material assistance as they can. It is necessary to create a fine political environment for soft science research by encouraging researchers to tell the truth and giving them full power and freedom in conducting research independently in accordance with scientific theories, methods, and facts. He hoped that soft science personnel will dismantle the old practice of ownership of academic departments, develop lateral ties, and direct their energies to the practical issues of economic, scientific, technological, and social developments.

Vice Governors Yang Jike and Wang Houhong attended the seminar. Comrade Yang Jike delivered a speech entitled "How Soft Science Serves the Development of China," on the first day of the seminar.

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CSO: 4008/5

NATIONAL DEVELOPMENTS

SHANGHAI BECOMES CENTER FOR ASTRONAUTICS TECHNOLOGY

HK150309 Hong Kong ZHONGGUO TONGXUN SHE in Chinese 1428 GMT 10 Sep 86

[Report: "Shanghai Has Become an Important Base of China's Astronautics Industry"--ZHONGGUO TONGXUN SHE headline]

[Text] Hong Kong, 10 Sep (ZHONGGUO TONGXUN SHE)--According to reports from Shanghai, Shanghai Municipality, with its well-developed scientific and technological system, has now become one of China's important bases of astronautics technology. The municipality was involved in the development and launching of 9 out of the 18 man-made earth satellites that China has launched so far.

Su Shikun, director of the Shanghai Municipal Astronautics Bureau, recently revealed that Shanghai began to develop carrier rockets in late 1969 and, soon after that, in the early 1970's, the municipality began to undertake the development and launching of large-sized man-made satellites.

So far more than 300 scientific research organizations, institutes of higher learning, and plants in Shanghai have engaged in the design, development, and building of carrier rockets. They have developed their own specialities in the fields of microelectronics, infra-red technology, automatic control, telecommunications technology, and remote sensing technology.

All astronautics experts from the United States, the United Kingdom, France, and Brazil who visited Shanghai in recent years expressed their appreciation of Shanghai's achievements in the field of astronautics technology.

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CSO: 4008/4

NATIONAL DEVELOPMENTS

TECHNOLOGY IMPORTS' IMPACT ON SHANGHAI INDUSTRIES DISCUSSED

Beijing RENMIN RIBAO OVERSEAS EDITION in Chinese 23 Jul 86 p 3

[Text] In Shanghai Municipality, technology transfer imports for the transformation of medium and small enterprises have shown results. During the past 3 years, more than 330 imported technologies have been completed and put into production. This has changed the technical face of a number of industries. There has been a large increase in the production of medium- and high-quality commodities, and the economic benefits are clear.

According to ministry statistics, from March 1983, when a State Council report approved the trial expansion of powers for medium and small enterprises for importing technology, to the end of June 1986, Shanghai Municipality signed a total of 894 agreements with foreigners for technology imports. The value of the agreements is $912 million. Over 90 percent of the projects are for technology at the international standards of the late 1970's and early 1980's.

The more than 330 technology import projects that to date already have been completed and put into production are beginning to reverse the technical aging of Shanghai industry. Technical standards have been raised in the metallurgical, bearings, low-power appliances, food products, household appliances, television and radio, plastics, knitting, printing, and other industries. For example, in the food products industry, 83 percent of state factories have imported technologies and have transformed the previous patterns of primarily manual operations and substandard sanitation. The products of the radio and television manufacturers are presently being improved in terms of functions, variety, and increased use of integrated circuits. The quality of the principal products and their technical and economic benchmarks meet the international standards of the late 1970's. In the knitting industry, conditions have been improved in 70 percent of the factories. The use of many pieces of advanced equipment has raised the grade of products and also has resulted in expanded variety. The ferrous metallurgy industry is presently expanding electrical furnace refining, continuous ingot casting, and high-speed wire rod production. As a result, continuous casting has increased from 27 percent during the Sixth 15-Year Plan to 30 percent, the proportion of low-alloy steel has risen from 10 percent to 15 percent, and the proportion of superior-quality steel has risen from 25 percent to 35 percent.

This group of projects involving technology imports that have been completed and put into production and key technical improvements have greatly improved product quality and strengthened the capacity for technical invention in Shanghai industries. At present, the municipality has 2,234 industrial products that have obtained the superior-product designation by the state, a ministry, or the municipality. The value of superior-quality goods compared to the total value of Shanghai industrial production has risen from 10.8 percent in 1981 to over 20 percent. There are already more than 1,330 products that use or refer to international standards-setting organizations. There are 337 key products that have caught up with advanced international standards.

Among the technology imports that have already been put into production, there are many that have raised the production capacity for medium- and high-quality products. This has made possible the significant increase in the production of medium- and high-quality products to meet market demand. In Shanghai between 1980 and 1985, watch production increased 42 percent, bicycle production increased 65 percent, camera production increased 1.6-fold, television set production increased 3.4-fold, tape-recorder production increased 7.9-fold, household washing machine production increased 135-fold, household refrigerator production increased 47.6-fold, and electric fan production increased 1.7-fold. The total value of industrial production in Shanghai during the Sixth 5-Year Plan increased more than 80 billion yuan over that for the Fifth 5-Year Plan. Thirty percent of that increase was due to technical advances.

12994/9435
CSO: 4008/2116

LEGAL ADVICE OFFERED TO S&T PERSONNEL IN SHANGHAI

Beijing RENMIN RIBAO OVERSEAS EDITION in Chinese 23 Jul 86 p 4

[Text] The Legal Advice Office of the Shanghai Science Association provides legal services to technical staff. It uses legal measures to help further healthy progress in the expansion and application of S&T.

Not long after the Legal Advice Office was established in 1985, it used opportunities when S&T personnel were gathered together to set dates for organized study of legal documents such as the Constitution, the Economic Contract Laws, and the Patent Law. This increased the legal knowledge of S&T staff and raised awareness about the legal system.

The Legal Advice Office receives visits at any time from S&T staff with legal questions. It carefully records the case, answers all questions, and provides considerate, convenient service. An engineer of the Shanghai Broadcasting Equipment Factory used time after work to design a new product. He also offered technology transfer and consulting services. His unit responded by circulating a notice of criticism. Moreover, he was not given the income he was owed nor was his probationary part membership processed. After careful investigation and study, the Legal Advice Office submitted a report to the municipal party committee, which resulted in proper resolution of this problem. The legal rights and interests of S&T personnel were protected.

A member of the municipal architectural association wanted to use time after work to engage in ground construction planning. Moreover, he was going to set the fees himself. But he was not sure whether this was legal or not. The Legal Advice Office pointed out to him that based on relevant State Council regulations, units or individuals who do not have a survey design certificate cannot accept ground construction work. As a result, this S&T staff member abandoned his original plans.

In a little more than a year the Legal Advice Office of the Shanghai Science Association has been visited by 118 S&T staff members and their dependents, involving 104 cases of all description. The majority of these cases were properly settled.

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CSO: 4008/2116

DEVELOPMENT OF SHANGHAI'S CONSULTING INDUSTRY DISCUSSED

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENCE OF SCIENCE AND MANAGEMENT OF S&T] in Chinese No 7, 12 Jul 86 pp 36-39

[Article by the Shanghai Scientific, Technological and Economic Consultation Corporation: "The Rise and Development of the Science and Technology Consulting Industry in Shanghai"]

[Text] Since its inception in 1979, Shanghai's consulting industry has grown continuously for 7 years and gradually become an indispensable industrial branch in the city's economic structure. And consultative research has also reached a new level. The important signs are: the industry is now capable of providing consultative services for major state policy decisions; it has attained the academic level to develop international cooperation in scientific research; a number of academic leaders in various disciplines have come forward; a consulting industry and policy consultation system is taking shape; and its impact is felt far and wide.

The development of Shanghai's consulting industry can be divided roughly into four stages:

1. The inchoate or spontaneous stage (1979-1981). During this period, in keeping with the trend of the times and society's demands, a few pioneers in consultative research set up some consulting organizations. Most of these organizations were not independent. On an exploratory basis, the municipal science and technology commission gave them 48 small-scale soft assignments, and the consultation industry made its first important step forward.

2. The expanding stage (1982-1983). To support this new industry, the municipal science and technology commission and the municipal education and public health office jointly established 12 soft science research institutes, which undertook the consultation and appraisal work on such major projects as "upstream diversion," "harbor site selection," "central heating" and so forth, which ranked high on the city's agenda. Their work caught the attention of the city's leadership and the public, marking the first major success of the consultation industry.

3. The fast-growing stage (1984). On the one hand, owing to the reforms and the opening of the technology market, the demands for Shanghai's technology by

other parts of the country increased sharply, leading to the vigorous growth of the technical consultation industry represented mainly by the municipal science and technology association's consultation center. Many consulting enterprises were established one after another. On the other hand, after successfully completing several major consultation jobs, the municipal science and technology commission formed a brain trust comprising more than 1,600 specialists in the city and provided organized large-scale consulting services on the city's 15-year science and technology development plan and economic and social development strategies, which promoted the simultaneous development of strategic consultation and technological consultation.

4. The formative stage. After several years of development, the consultation industry is beginning to take shape in Shanghai, as relevant laws and regulations and management are being perfected.

Shanghai's consultation industry has made important contributions to the formulation of social and economic development strategies, transformation of traditional industries with new technologies and earning foreign exchange from exports.

1. Providing Consultative Services for Overall Policy Decisions on Economic and Social Development Strategies.

In 1983, a "brain trust" was formed with more than 1,600 specialists from the scientific research, education, production, economic and other trades and professions in Shanghai (tens of thousands more participated in the work indirectly). Under the leadership of the municipal science and technology commission and proceeding from the coordinated development of Shanghai socially, economically and in science and technology, they conducted investigations, studies, forecasts and appraisals on a 15-year (1986-2000) scientific and technological development plan for Shanghai, carried out special research on 79 new fields, key industries and major social problems, and made forecasts on the city's energy, population, trained personnel and other social and economic problems. Using more than 70 quantitative methods, they processed more than 10 million data items and wrote consultative reports totalling more than 17 million words, which recommended development in 7 new fields (microelectronics, new materials, etc.) and 22 key industries, presented a "scientific and technological development strategy for Shanghai by 2000," and proposed the fighting goal to build Shanghai into an "open, multifunctional, modern, socialist city with a rational production structure, advanced in science and technology and culturally highly developed," unfolding a great plan for Shanghai's development.

2. Giving Counsel on Ways to Solve the City's Traffic, Environmental Protection and Other Major Social Problems.

Shanghai has a very serious traffic problem with a daily commuting population of 1.6 million and 300 motor vehicles and 1 million bicycles per kilometer. Each day, an average of 22 traffic accidents occur, and 11 people are killed or injured. How can the traffic problem be solved? It certainly cannot be solved simply by increasing the number of vehicles and expanding the roads.

In 1983, the municipal science and technology commission and capital construction commission ordered organization of the "Shanghai urban traffic consultative study" project. A great deal of statistical and analytical studies were conducted including a feasibility study on building subways in the urban area, a comparative study on subway systems and structures in different cities and countries, and particularly a study on Hong Kong' subway train models, power supply, communications, operations and management. More than 50 special and general reports were prepared on the construction of a subway system in Shanghai, which are being used as the basis for solving the city's traffic problems in a systematic way and drawing up transportation development plans.

3. Providing Feasibility Appraisals on Major Projects.

A good example is the "feasibility consultation on the Baoshan Iron and Steel Complex Changjiang (reservoir construction) diversion project," which won the only first-class science and technology award in Shanghai in 1985. By changing the original plan and diverting water from the Changjiang for the Baoshan Iron and Steel Complex, construction costs were cut by more than 50 million yuan every 6 months, and power consumption by more than 25 million kilowatt-hours each year. These figures show the importance of consultation.

4. Providing Consultative Services for Decisions on Importing Technology and Equipment.

In 1982, Shanghai's annual foreign exchange earnings increased to $300 million. With so much money available and so many needs for technical transformation, the question was what to import. Proceeding from the actual requirements of Shanghai's economic development, we selected 27 major projects as the city's priority recipients of imported equipment and technology, including those for product upgrading and updating and other key technologies. Examples were electron cameras, thin-type women's wrist watches, updating of the "four big items" of light industrial products, and essence and perfume, cosmetics and packing technologies. Generally the investment was recovered in 1 or 2 years, and earnings in foreign exchange continued. This has produced a great impact on Shanghai's economic development in the past few years.

5. Providing Consultative Services on Research and Development of New Products and Maintaining Rate of Production Increase.

The key to production growth lies in the manufacture of highly marketable goods. In the 3 years since its establishment, the municipal science and technology association consultation center has done a lot of work in developing new products and providing technical consultations. In the 3 years, it has provided technical consultations on more than 12,000 items, which are directly attributable for the earning of 600 million yuan in profits, contributing to production increases in Shanghai and other provinces and cities and to development of horizontal economic ties.

6. Providing Management Consultations for Enterprises to Grow

Enterprises are the basic cells in economic activities, and modern business administration is a synthetic science. All other conditions being equal, management is the decisive factor. In the past few years, management consultation services have also developed vigorously in Shanghai. Many consulting organizations have helped enterprises in applying value engineering to modern enterprise management with marked economic results.

7. Providing Information Services for Trade and Technical and Economic Cooperation With Foreign Countries.

Shanghai is China's major export city. Information and consultation are extremely important to foreign trade and technical and economic cooperation. After many years of efforts, the municipal foreign economic relations and trade computing center has established step by step a foreign trade information center, which at present is the largest in China. The center has an average annual data input of more than 30 million words and stores materials on nearly 30,000 clients in foreign trade and information totalling more than 1 billion words. The foreign trade information center has the largest storage capacity and the largest number of applied systems in China. It provides all parts of the country with the information needed in foreign trade forecasting and decision-making.

8. Serving Foreign-exchange-earning Exports.

Since it was established in 1982, the Shanghai Mechanical and Electrical Products International Consultancy Corporation, the first private corporation of its kind in China, has dedicated itself to serving industry and foreign trade and promoting exports. So far it has undertaken more than 1,000 consulting jobs, established ties with chambers of commerce, industry and commerce associations, banks and other trade liaison organizations in more than 280 economic centers and cities around the world, and maintained regular business contacts with more than 1,500 domestic clients. It has provided Shanghai's exporters with efficient, prompt and flexible consulting services. The corporation had a net income of more than 300,000 yuan from consulting services in 1985, making it one of the best performers among the consulting organizations in Shanghai.

9. Suggesting Ways for Training Specialized Personnel for the Four Modernizations.

Although Shanghai has a large number of trained people, nationwide it ranks only 10th in this respect, which falls far short of what is needed for the city's economic development. In 1983, we set up a data base on the city's trained manpower. Through a great deal of analyses and forecasts, we brought up the question of Shanghai's "manpower gap" and presented three intellectual resources development plans aimed at multiplying trained manpower, which were accepted by the municipal government as the basis for decisions on the city's training work.

Shanghai's consulting industry has gradually acquired its own characteristics.

1. Integration of the overall with the specific. In consultative research, it is imperative to be good at combining the overall with the specific

approaches. We must not study a problem from one plane, but should study and analyze it from different planes and levels.

2. Integration of the soft with the hard. Consultation is a branch of science, a soft science with hard techniques. This is one of the most important characteristics of modern scientific and technical consultation.

3. Integration of the systematic and comprehensive with the particular and outstanding. The difference between consultation and suggestion lies in that consultative research should produce a more comprehensive plan for the solution of a problem. That's what is expected of all better consulting organizations.

Shanghai's soft science research and consulting work have developed by probing and exploring. Our experience consists mainly of the following.

1. The Key to Successful Consultation Lies in Having the Proper Subject

As consultative research is to serve the policy-makers or clients, it is distinctly practical and purposeful. It is practical as it is aimed at providing policy-makers with plans to solve practical problems, and not at developing a certain branch of learning. It is purposeful because it is aimed at solving complicated problems by systematic and comprehensive considerations as well as penetrating insight.

Therefore, the subject of consultative research cannot be too broad, causing people to stray from the main point and the results irrelevant. Nor can the subject be too narrow, which will result in a lack of supports and props for the decisions and plans recommended. This is why many specialists feel that "having the proper subject is one half of a successful consultation."

2. Rational Personnel Organization Is Foundation for Development of Consultative Research

Problems requiring consultative research are changing all the time, and generally they are complicated and involve many different departments, disciplines and professions. Few, if any, research institutions have the functional and personnel structures needed to tackle these problems. Therefore, in major consultative research projects, the basic prerequisite for success is rational organization of personnel.

From experience, we have learned that to conduct an overall strategic study, it is generally necessary to form a research project group according to requirements. A research project group should include three types of people: first, experts in strategic and policy research, capable of conducting synthetical and analytical studies; second, systems engineering specialists who are able to use scientific methods to make forecasts and analyses; and third, specialists in relevant fields. They are the basic personnel in the study of a problem. Based on the scopes of problems, three organizational forms are used for consultative research:

First, the "ladder-shaped structure." Used mainly for overall strategic consultations. Research projects of this type generally deal with overall policies and plans and major engineering projects. The research project group consists of five parts. 1) Leading group, composed of leaders of the client organization and the research project group, who provide "guidance," engage in "dialogues" and open up "channels" for the project. 2) Overall group, composed of experts in policy research, system engineering and other relevant specialties, which is the core of the entire project, responsible for the operations of the project and the end results. 3) Advisors group, composed of "authorities" in the disciplines, managements and professions involved in the research, who provide guidance on key problems arising in the course of research. 4) Research project subgroups, which are formed by breaking down the research project into a number of subprojects. 5) Experts group, which invites experts from certain professional fields to provide consultations on specific research problems, largely organized by the research project subgroups. For example, this was the way the research project group was structured when we were assigned by the State Science and Technology Commission last year to prepare a "forecast on the prospects of the use of microelectronics technology in China." Experience has proven that this form of organization is in keeping with the actual conditions in China today.

Second, the "horizontal structure." Used mainly for consultation in a specific field. Even though research projects of this type do not have overall importance, they still involve quite a few departments and professions, and it is necessary to get units and experts in several fields organized. First of all, the science and technology commission should select a few major units as the leading units and help them get organized. These leading units will then organize specific research projects. This organizational form is proven effective for consultative research in a specific field for use in long-range science and technology planning, research, forecasting and appraisal. For example, a "biotechnological" plan was worked out with the Shanghai Biochemical Institute and Fudan University as the leading units and the participation of more than 10 other related units.

Third, the "point-shaped structure." This is generally for the narrower research projects. These projects are often undertaken by one research institute, which engages "consulting experts" according to needs. For example, the "model appraisal and decision procedures for industrial investment in Shanghai" was undertaken by Shanghai Finance and Economics University. In the course of the research, attention was paid to investigations and studies, and "consulting experts" were engaged from relevant departments.

It should be pointed out here that the selection of leaders for the research project groups is a matter of great importance. Special attention should be paid to choosing experts, who are dedicated, highly accomplished academically, erudite and good at promoting unity and cooperation, to be leaders of research project groups.

3. The "Four Links" Hold the Key to Successful Project Research

How well is a soft research project or consulting project accomplished? Is it a success? The key lies in "four links" of work. The "four links" are investigation and study, scientific processing, synthesis and analysis, and appraisal by experts.

First, investigation and study for collection of data. Information is the basis of consultative research. There are two kinds of information. One is basic scientific data, which is absolutely necessary. Owing to the backwardness of statistical work and the lack of data bases in our country, much of our data is unscientific, inaccurate, incomplete, unreliable, and even nonexistent. The other kind is typical information on actual conditions, policies, management problems and so forth. All such information can only be obtained through investigations and studies. Therefore, the most fundamental method of consultative research is to conduct a great deal of investigations and studies to make on-the-spot surveys and obtain scientific, quantitative, firsthand information.

Second, scientific processing. The fundamental difference between modern consultation and empirical consultation is that in modern consultation soft science is applied to study and analyze the laws governing the development of things, establish relevant mathematical models, carry out data analysis and processing, and so forth. Without this part of the work, the consultative report will become an ordinary "investigation report," as it is not based on soft scientific research.

Third, synthesis and analysis. Some consultative projects concern important policy and strategic questions, and it is imperative to put forward some strategic viewpoints and policy suggestions on the basis of the results of the investigation and study and scientific processing and through synthesis and analysis according to the laws governing the development of things, to serve the leaders in making decisions.

Fourth, appraisal by experts. Consultation itself involves listening to opinions of experts in various fields. Therefore, the timely invitation by the research project group of experts from various fields to appraise the subject, methods and results of the research project is an indispensable link of consultative research. By combining the specialized research of the project group with the timely appraisal by consulting experts, the correctness of the consultative conclusion will be greatly enhanced.

4. Proper Coordination Is the Guarantee for the Success of Consultative Research

Consultative research requires a wide range of knowledge and talents and that questions be studied in a systematic way. This makes it necessary to break down four organizational barriers, namely, the barriers between trades, between disciplines, between departments and between areas, so that experts in the scientific research, industrial production, economic, legal and other fields can be properly organized. In this, coordination plays an extremely important role, and it is also a professional skill.

First, coordination between higher and lower levels. In consultative research, it is important to obtain the timely support from the leadership of departments concerned, which often spells the difference between success and failure in getting the personnel and information needed from these departments.

Second, lateral coordination, that is, coordination between the research project group and units related to the project. For the city's major research projects, the municipal authorities should step in to open up doors. At the same time, the research project group should also take the initiative to establish good lateral relations.

Third, coordination within the research project group. Harmony and agreement within the research project group are particularly important to the success of the project. The combined effect is far greater than the sum of the individual units added together, but poor coordination will result in just the opposite. Generally major research projects should be organized by the municipal science and technology commission, and then turned over to the units to which the leaders of the research project groups belong. At the same time, it is necessary to coordinate the contents and progress among the subprojects and other related projects as the work moves along.

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CSO: 4008/2123

NATIONAL DEVELOPMENTS

BENEFITS OF HOSTING INTERNATIONAL CONFERENCES DISCUSSED

Beijing RENMIN RIBAO in Chinese 3 Jun 86 p 3

[Article by Chen Zujia [7115 4371 3946]: "Chinese Science and Technology Association Expands International Scholarly Exchanges"]

[Text] In recent years, the Chinese Science and Technology Association has fully used the strengths of mass organizations to convene larger numbers of international conferences, striving to draw to China ever larger number of foreign experts and scholars for scholarly exchanges.

According to statistics provided by the International Conference Center of the Chinese Science and Technology Association, there have been more than 700 conferences of various kinds sponsored during the past 6 years by the Chinese Science and Technology Association and its constituent associations. Each year, it has accepted an average of more than 10 invitations by international organizations to sponsor international meetings. More than 30,000 foreign experts and ethnic Chinese scholars have come to China to participate in these exchanges.

At the same time, the Chinese Science Association has sent more than 3,000 persons abroad to observe, study, conduct research, and attend international S&T meetings. The Chinese Science and Technology Association has recovered its rightful places on the board of directors of the International Science Congress and in the International Association of Engineers. More than 200 scientists have been chosen to serve leading roles in international scholarly S&T organizations.

The expansion of international scholarly exchanges plays an important role in the pursuit of global high technology, in the expansion of the horizons of S&T personnel, and in promoting the reputation of China's S&T. Through participation in international conferences, the Chinese Medicine Association learned that much attention abroad was directed at thyroid gland research. It then established new topics related to basic medical research. Chinese specialists learned of new directions abroad when they attended an international spectral iron [Tiepu] conference. This helped advance China's spectral iron technology. After attending an international conference on permanent magnetism in rare earths, Chinese specialists used the knowledge that was obtained to advance research in permanent magnetism in rare earths, and in other subjects, and in electrical applications.

During these international conferences, Chinese scholars presented more than 20,000 papers, displaying the results of Chinese research and drawing the interest of foreign colleagues. When the Chemistry Institute of the Chinese Academy of Sciences presented scholarly reports at the "international conference on heterocyclic chemistry," foreign colleagues immediately came over to exchange news and set up cooperative research links.

Convening international scholarly conferences in China brings large benefits to younger S&T personnel. At present, only one in a thousand among China's S&T personnel have the opportunity to attend international conferences abroad. Convening international conferences in China is an important channel so that the others can learn of new thinking, new trends, and obtain the latest news. The words of a graduate student are representative: "At the moment we do not have the opportunity to go abroad to study, but we are able to participate here in China in international scholarly exchanges. The benefits are great." In recent years, among the almost 60,000 S&T personnel who have participated in international scholarly conferences convened in China, 60 percent are middle-aged or young scholars. Ninety percent of the Chinese attendees at an international conference on finite elements, sponsored by the Chinese Architectural Association and three scholarly associations, were middle-aged or young scholars. Graduate students, who in the past rarely attended international conferences, also have begun to enter the scholarly forum.

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NATIONAL DEVELOPMENTS

BIOENGINEERING PROSPECTS EXAMINED

Shanghai HUAXUE SHIJIE [CHEMICAL WORLD] in Chinese, Vol 27, No 5, 25 May 86
pp 225-228

[Article by Wang Zhen [3769 4631]]

[Text] Bioengineering [sheng wu gong cheng 3932 3670 1562 4453] is a product of the combination of the biological sciences and scientific technology; it can be referred to as biotechnology [sheng wu ji shu 3932 3670 2111 5890]. Its scope is broad; it includes genetic engineering, [ji yin gong cheng 1015 0936 1562 4453], enzyme engineering, [mei gong cheng 5326 1562 4453], fermentation chemistry, [fa jiao hua xue 4099 6806 0553 1331] and other sciences. It is a young science, its name appearing only in about the last 10 years. It is also ancient; its source can be traced to several thousand years B.C. In those times, even though man was not aware of microorganisms, they still used fermentation to prepare wine, vinegar, food products, etc. In 1979, genetic recombinant technology was successfully used in industrial chemical production. This was a landmark achievement.

I. Advantages of Bioengineering

Bioengineering, as a new technology, has many advantages over traditional technology and conventional methods. These are roughly as follows:

(1) On the basis of the cyclical nature of bioresources, prevent the depletion of the world's limited resources.

(2) Direct the creation of new products to suit the needs of many fields.

(3) Raise efficiency and shorten production cycles.

(4) Change waste into something of value, and change disadvantages to advantages, without creating pollution.

(5) Develop clean production for industry, an inexpensive route to important biological products.

These few advantages are generally acknowledged throughout the world, though there are differing views on their significance.

II. Differing Views on Bioengineering

The United States considers biotechnology to be revolutionary in chemistry. There are people who say biotechnology is the "science of today, the technology of tomorrow, and the product of the day after tomorrow." "Biotechnology will be as big in the 21st century as chemistry and physics have been in the 20th century." It is also said: "The next 20 years will be the era of biotechnology just as the last 20 years was the era of microelectronics."

Japan attaches much importance to biotechnology, each year investing approximately 400 million yen and strengthening the scientific organization and information network. Science and technology circles raise the following point which really provides food for thought: "From now on, there will not be a return to a mineral era but there will be a 'bio-era.' Whoever seizes biotechnology will be the master of the times."

The Soviet Union thinks biotechnology will be a rich and rewarding field of knowledge. By utilizing the world seed pool, crops suitable for growth in the Soviet Union can be cultivated. Genetic engineering [yi zhuan gong cheng 6695 0278 1562 4453] can be used to produce amino acids and vaccines.

Generally speaking, there are a few western European countries that are sceptical about biotechnology. First is whether biotechnology is more fruitful than other technologies. Second, people harbour psychological fears concerning genetic engineering. Third, classical biotechnology guarantees safe and honorable responsibility. Fourth, the propaganda of biotechnology should address more the practical aspects. Now, they are hurriedly catching up.

III. Situation in the United States

In biotechnological research, the United States has all along held the leading position. Following "Silicon Valley," there rose up "Bioengineering Valley." In the suburbs of Washington, D.C., and in California, Maryland, and Boston, there are several hundred bioengineering centers utilizing an enormous amount of manpower and material resources. To date, about 1,000 biotechnology patents have been applied for at the U.S. Patent and Trademark Office. The following products of genetic engineering have entered the market: sheep growth hormone, "heliotropic beans," etc. An investigative report by the Office of Technology Assessment of the U.S. Congress said: "Now, in the field of bioengineering research, there is the potential threat that the world leadership position is held by Japan." It proposed that the federal government do the appropriate research and expand capital assistance.

In the field of recombinant genetics, the United States has started to carry out field experiments on organisms produced by genetic recombination methods, for example, field experiments on recombined maize, tomatoes, alfalfa stem mycocecidium, etc.

The United States, taking bioengineering as a basic enterprise, last year underwent some adjustment. Following that, stock prices rose sharply, at year's end reaching 121 percent, while those of general chemical plants were up only 28 percent. This greatly inspired confidence in bioengineering research. Monsanto Company, DuPont, and others invested heavily. Because biotechnology is a swiftly developing sector, before 1990 there will be a need for an additional 5,000 fermentation technicians and engineers, and by 1995 the need for this type of specialist will reach as much as 35,000, and only in this way can the world leadership position be assured. The United States will set up many more biotechnology centers. Key items are: (1) research on weed killers, pesticides, etc.; (2) research on food additives; and (3) research on fermentation technology. Items (1) and (2) will protect their leadership position; moreover, they are fine chemicals, and profits are high. According to estimates, in 1989, the growth rate of the "new" biotechnology (mainly genetic technology and cell cultivation) compared to the "old" biotechnology (mainly microorganisms and enzyme technology) will be higher by 27.5 percent.

According to the most recent reports, the United States has "Nine Stars of High Technology." One of these is "Biotechnology--Industrial Market Potential Without End. Today, the greatest market for biotechnology is in the agricultural field, for example, seed companies; next is food products and medicine. In the future, the fields most challenging to biotechnology will be in the area of malignant disease protection."

IV. Situation in Japan

Regarding bioengineering in Japan, although the "new" biotechnology landed there later than in the United States, the "old" biotechnology is ahead of the United States. The competition between the two countries is intense. Japanese believes that for rapid development in the promotion of bioengineering, they must set up more agrobiological resource research departments for bioengineering research in Tsukuba Science City, and also resolve five problems: (1) research into "biological reaction mechanisms"; (2) research in new types of pesticides and the development of cell culture technology; (3) adoption of cell fusion techniques and research-improved microorganism and plant cell technology; (4) adoption of immunity methods and research on simple and rapid diagnoses for epidemic diseases among livestock; and (5) adoption of tissue culture methods and research on high-efficiency production seeding technology. Japan is preparing to use genetic engineering to cultivate "high-yield crops" and "non-fertilizer using crops," focusing on vegetables, flowers, and fodder. In 1983, Japan invested U.S.$200 million in genetic recombination and founded 120 companies and decided to take measures to accelerate the cultivation of bioengineering research talent and to strive to increase manpower in this area 4-fold within 10 years to surpass the technological standard of the United States.

Japan believes that the coming field of biotechnology is that of plant seeds. It will be the newest focal point in the international agricultural industry. The Japanese government has increased investment in biotechnology research, subsidized research jobs among the people, and stepped up the collection of seeds and other genetic raw material from around the world. One analyst said: "Whoever dominates the seed market can rule the world." Presently, Japan is officially doing research on taking protein-containing genetic factors from kidney beans and transferring it to tobacco and American herb cells, with the intention of making an edible tobacco leaf. Japan is considerably advanced in various aspects of fermentation technology. Because of this, Japan has made a good beginning in the pharmaceutical applications of biotechnology, but it still lags behind in the non-fermentation spheres. This situation requires vigorous development in the seed industry.

In 1984, Japan successfully utilized recombinant gene technology to produce a growth hormone from salmon using a batch process. This was the world's first utilization of recombinant gene technology to obtain a growth hormone from salmon. This type of product demonstrates a previously anticipated function; from now on, applied research can be carried out. The production of fish growth hormone also contributes to research into biological evolutionary processes.

Biotechnology has become the center of attention in Japan and the scope in medicine and food additives is expected to be extended. Japanese enterprises enhance bioengineering information and popularize the work. They do not hesitate to spend money to purchase the technology. They have signed approximately 15 biotechnology transfer agreements with U.S. companies, most importantly dealing with gene-splicing technology.

V. Situation in the Soviet Union

Soviet scientists generally consider bioengineering to be the realm of knowledge which will achieve the largest number of discoveries and the main technology to resolve the livelihood problems of the contemporary world population, for example, high-yield crops, good-quality livestock, specific drugs, etc. The Soviet government also set up specialized scientific research institutions such as genetic storehouses for the collection of cell tissue, animal gene storehouses for preservation of existing genes, information centers for animal husbandry genetic data, etc., thus accelerating the development of bioengineering technology. Presently, it has formulated a nationwide bioengineering program. The development of bioengineering is one of the three main directions of the current 5-year plan. They demand that the rate of development of bioengineering be faster than that of other industries, and change the direction of the agricultural industry. The Soviet Waweiluo [phonetic] Crop Cultivation Institute has collected more than 340,000 types of cultivated plants from around the world. These crops cannot adapt to the harsh climate of many areas of the Soviet Union. However, they could be used as a source of supply to be suitably cultivated to grow as short-stem crops in the Soviet Union and could be very effective. For example, using cultivated barley seed from Canada, Holland, Norway, the United States, France, and Czechoslovakia, the potential output could reach 80 quintals per hectare. The rice paddies of the Soviet Union could have cold resistance using rice strains from Brazil, India, Cuba, and

Japan. The Soviet Union uses the world's seed pool to cultivate new products and, for the first time, cultivated a free-standing, disease and pest-resistant, high-yield pea plant.

According to one scholar, the Soviet Union is in the leadership position in the area of biotechnology, due to the rapid growth of the internal development of basic technology. Starting last year, it used genetic engineering production technology to produce interferon. It is in the last phase of that work. Research work on gene splicing for insulin and human growth hormone is already completed. The Soviet Union is considering important locations for setting up biotechnology centers. The most recent achievement was the use of genetic engineering to produce amino acids.

VI. Situation in the Western European Countries

The Western European Biotechnology Federation Marshall Haowenke [phonetic], in a 1985 report of the Third Western European Biotechnology Conference, thoroughly probed several problems related to biotechnology. He pointed out that many news reports related to biotechnology caused a sensation. This, then, gives people an impression that biotechnology seemingly is an all-purpose key for solving problems. In the field of synthetic medicine, for the entry of one new product into the market, it is necessary to synthesize between 5,000 and 10,000 chemical compounds and successful completion of the synthetic techniques requires 10 years. We need to see that the development of biotechnology is analagous to this. In the area of borrowed genetic engineering, human insulin is a milestone, having used bacteria in the laboratory for the first time and having produced insulin after only 4 years. There is widespread fear among the public concerning genetic engineering. An accident or the recognition of negative consequences can give rise to public fears and have a serious effect on the future development of biotechnology. With "safe biotechnology" as a problem discussed by the specialists, the federation work group for the industrial microorganism safety question indicated the following results: in classical biotechnology, including basic production of vaccine against pathogenic microorganisms, safety was evident; bioengineering should promise the guarantee of safe and honorable responsibility. Haowenke proposed that education in genetic studies and evolutionary biology be carried out in the schools to show what can be accomplished in the future with newly developed work. Then, the fear of the unknown and conflicts with technological innovations can be overcome.

Great Britain successfully produced an anti-schistosomiasis vaccine through experimental genetic techniques. More widespread production will take still more time.

In 1982, France proposed a 3-year mobilization plan for bioengineering, increasing its investment in bioengineering research. French companies are also making preparations.

West Germany, in support of biotechnological research, will budget 1 billion German marks in funds between 1986 and 1989, decided to establish a center for fundamental research, and will subsidize about one-half of university development research. Industry requires a large number of biologists.

Austria, in promoting biotechnology, emphasizes a bioengineering and genetic technology program, providing 200 million Austrian schillings. In this program, cell cultivation and fermentation technology hold priority positions.

The Degusa [phonetic] Company and the Biotechnology Company in Sweden consider the prospects for tryptophane technology to be broad. These two companies are now doing joint industrial-scale research.

The Spanish biotechnology program has set up a research center, undertaking research work in biotechnology as a combined scientific research activity of each region. The center trains specialized personnel, disseminates biotechnological information, and promotes research and development enterprises.

VII. Concluding Remarks

From the above account, it is seen that many countries attach great importance to bioengineering; the prospects are great and the economic benefit to and social influence on mankind will be great. China is also among the nations in which scientific and technological research is emphasized. China is preparing to establish a "Bioengineering Research and Development Center" in Shanghai. Fudan University has set up a life sciences institute, the first among institutions of higher learning. Based on the need to develop this branch of learning, the Fudan University Life Sciences Institute will strengthen the structure of the genetics research department, while at the same time proceeding to set up the genetics and genetic engineering department, the microorganism and microorganism engineering department, the biochemistry and biochemical engineering department, the biophysics and physiology department, and the biological material and environmental biology department, and will also set up a virology and a number of other research laboratories. The Biology Department of the Shanghai Science and Technology University is also emphasizing the "bioengineering" specialty. We need the determination not to lag behind and to try hard to catch up, achieve brilliant successes, and make great efforts to bring credit to the homeland.

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NATIONAL DEVELOPMENTS

BOHAI BAY ECONOMIC, TECHNICAL DEVELOPMENT ZONE DISCUSSED

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENCE OF SCIENCE AND MANAGEMENT OF S&T] in Chinese No 6, Jun 86 pp 15-16

[Article by Yang Haitian [2799 3189 3944]: "A Preliminary Study on the Establishment of Bohai Bay Economic Zone"]

[Text] I. Bohai Bay is the largest bay of the continental sea, stretching from Dandong [0030 2639] to Qingdao, with a dozen coastal cities forming a uniform circular formation. This area has its own characteristics and superior points.

1. Geographic superiority--The Bohai Bay area is composed of Liaodong peninsula, Shandong peninsula, Beijing, Tianjin and Tanggu, with the Bohai Sea in front, reaching to the Pacific Ocean, and the vast hinterland of Northern China, Manchuria, Northwest and Central China behind. The five large seaports of Dalian, Qinhuangdao, Tianjin, Yantai and Qingdao have trade with more than 150 countries and districts in the world and contact with every place in the country, with a dozen main raliway lines, 20 commercially used rivers, 50 airways and highway networks. This area is also the starting point of the two "inland bridges." The first is Dalian where commodities land and can be transferred through Manzhouli to join the Siberian Railway; the other is Tianjin where commodities land and can be transferred through Erenhot and Mongolia to join the Siberian Railway. We can say that the geographic superiority and convenience in communications and transportation in the Bohai Bay area are second to none.

2. Vitality in technology and educational strength. The Bohai Bay area is one of the areas with the highest S&T levels in the country; including Beijing, there are more than 100 regular colleges and universities, more than 200 technical secondary schools, 800 natural science research institutes and nearly 600,000 S&T personnel. In the place are gathered many important research institutes of the country, and many specialists and scholars who are well-known throughout the country and the world; in addition, it embraces a large troop of skilled old workers. This rich, intensive intellectual resource is second to none in the country.

3. Rich natural resources. The Bohai Bay area contains the four oil fields of Shenli, Huabie, Dagang and Liaohe, which embrace an offshore oil and gas

region of impressive reserves. It encloses several large coal mines such as Kailuan and Jingxi; and large iron mines such as Anshan and Jidong; it includes the salterns where more than half of the nation's salt is produced. Furthermore, the Shandong peninsula and Liaodong peninsula are also two famous agricultural areas. With such abundant natural resources, the Bohai Bay area can be called richly endowed by nature.

4. Vast space for further development. Along the 5,000 km coast line of Bohai Bay, there are saline and alkaline wastelands and beach accretions which provide favorable conditions for the expansion of productivity and construction of the economic and technical zone. Judging by the density of population in coastal cities such as Dandong, Dalian, Qinhuangdao, Yantai and Qingdao, the average is 1,700 per sq km, which is much lower than the rest of the other large coastal cities such as Shanghai (2,700 per sq km) or Guangzhou (2,300 per sq km).

II. The characteristics of Bohai Bay have determined the bay's importance in the economic and social development of our country, and they should have been used to best advantage. However, since the sixties, owing to the influence of factionalism, the original economic and social ties have been weakened and its superiority not fully utilized. For example, Tianjin, Dalian and Qingdao are superior in geographic location with high industrial technology standards, yet, for a long time, there were few arrangements about key items of construction in the three municipalities and there was a great gap in the supply of raw materials needed; each municipality had to resort to " large and complete", and according to national statistical classification, of the 164 different industries, there were 153 in Tianjin, 145 in Dalian and more than 100 in Qingdao. As a result, urban expansion became more and more serious a problem, there were many problems such as distribution of water, energy, and resources, construction of communications and transportation networks, and dealing with environmental pollution. Municipalities like Yingkou, Jinzhou, Tangshan, Qinhuangdao and Yantai embrace natural resources for tourism, with flourishing sea transportation, and they possess favorable conditions for the development of basic industry, tourism and ocean shipping. However, for a long time, due to the shortage of capital and technology, not only has this superiority not been fully developed, there still exist many problems in the distribution of industry in the municipalities and environmental protection, still less can we say they fully use their superiority. As the political, economic and cultural center of the country, Beijing should have played an important role in supporting the development of intellectual and technological resources; yet, owing to the one-sided emphasis on changing net-consumer municipalities into net-producing ones, the state poured huge investment into industry, which resulted in serious environmental pollution, and the intellectual superiority was not fully developed.

It is an important experience and teaching provided by history that the series of major local problems and contradictions in the Bohai Bay area can only be solved through comprehensive regional management. Since the Party's 3rd Plenum of the 11th CPC Central Committee, there has been restoration and progress in economic and technological coordination among the municipalities in the Bohai Bay; yet in regional economic development Bohai Bay obviously falls behind the Yangzi River delta, Pearl River delta or sourthern Fujian triangle. Today, when economic development is fast in our country and the world, the municipalities in the Bohai Bay area, besides exploiting their superiorities, should coordinate to make up each other's deficiences, to accelerate the realization of regional economic coordination, in order to accelerate the development of this area.

III. The demarcation of an economic zone and the establishment of its direction of development should meet the following objective requirements:

1. The extent of the economic zone and its direction of development must follow the overall plan of national economic development, to be an effective link of the organic part of the overall national strategy and of the chain of the whole economy.

2. Each member in the economic zone must give full play to its superiority, to create new economic results through coordination and division of labor.

3. Historical, cultural, social and economic links between different districts in the economic zone must be maintained and reinforced to form a closely coordinated system among the workers and peasants, urban and rural, different nationalities and geographic areas, to achieve obvious social interests.

4. The development of the economic zone must be favorable to environmental protection and ecological balance to create optimum ecological results.

Based on these points, this area, the Bohai Bay economic zone, through further reform and opening-up, should gradually be established. It should be an economic zone with its own characteristics, with the dozen large, medium and small coastal cities such as Dandong, Dalian, Yingkou, Panjin, Jinzhou, Tangshan, Qinhuangdao, Tianjin, Dongying, Yantai and Qingdao as the body; the three provinces and one municipality of Beijing, Liaoning, Hebei and Shandong as back; Manchuria, North China, Northwest and Central China as hinterland; the five economic and technological development districts of the five coastal cities as "windows" and the north part of China and the Asian Pacific region as the major stage of activities.

With the experience of the establishment of several other economic zones and combining the characteristics of this region, the following three points must be insisted upon in the establishment of the Bohai Bay economic zone: first, certain individual cities should not be used as the nucleus. Looking at the economic zones available in our country and the world, basically a certain large or medium city is used as the nucleus and other cities around it form a radial economic network. It is not so with the Bohai Bay economic zone; it is a colony composed of a dozen large, medium and small cities which form the nucleus of the economic zone, that is, the body of the Bohai Bay economic zone. Second, no clear demarcation lines are drawn. The provincial, municipal and city districts are administrative divisions in the scope of history and society. If the economic zone is drawn simply according to this administrative division, it is very unlikely to be scientific or reasonable. The present distribution of productivity has formed through the years. Under the circumstances that the economic divisions are not the same as administrative divisions, if administrative measures are taken first to adjust the present overall distribution, the interests of individual districts are bound to be difficult to coordinate, thus hindering the construction of the whole economic zone.

In the construction of the Bohai Bay economic zone, the following ten aspects must be considered:

1. Joint formulation of the strategy of development of the economic zone.
2. Deep development of economic coordination in the zone.
3. Establishment of a joint port organization and a communications and transportation network in the zone.
4. The establishment of a tourist area.
5. The establishment of an information exchange network.
6. Coordination of policies within the development zone.
7. Coordination between human resources and technology development.
8. Development of financial coordination.
9. Establishment of a Bohai Bay "common market."
10. Promotion of farming and animal husbandry around the sea.

In addition, there are many other aspects to tackle with great effort, such as how to formulate a unified plan about the 5,000 km coastline to promote comprehensive utilization and development, how to utilize the rich agricultural resources of the region to establish the commercial, industrial and agricultural economic structure with the characteristics of the north, or how to acquire a reasonable distribution of labor in offshore oil exploration, refinement and processing to establish our largest petroleum and ocean chemical engineering base.

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SMALL ENTERPRISES URGED TO PURCHASE TECHNOLOGY PRUDENTLY

Tianjin JISHU SHICHANG BAO in Chinese 1 Jul 86 p 1

[Article: "How Should Town and Township Enterprises Purchase Technical Findings"; first paragraph is source supplied introduction]

[Text] Town and township enterprises are distinguished by small capitalization and unsophisticated technical capability, therefore purchase of technical findings should emphasize the following points:

Editor's Note--At present, many town and township enterprises have actively purchased technical findings and have obtained considerable economic benefits. But there are also some which have made purchases blindly and have suffered losses. Many town and township enterprises have been hesitant in the technology marketplace and have written letters asking how to purchase technical findings. Comrade Li Junkan [2621 0193 0170] of the Jiangxi Economic Commission's New Technology Extension Station has provided some advice that can serve as a response to this problem.

1. Technical findings that are purchased should require little investment, go into production quickly, be easy to assimilate, and be appropriate for the domestic market. Consideration should also be given to economic returns, supply of raw materials, pollution, transport, and other factors.

2. Mature technical findings should be purchased because the findings can be put into production quickly, investment repaid quickly, and these findings are more dependable. For example, purchase of laboratory findings requires a certain amount of forecast and measurement capability. It also requires comparatively strong technical capability and large amounts of funds. So these findings would be risky for town and township enterprises.

3. Concrete reality should be kept in mind. Generally speaking, it is safer to purchase an entire technology, buying at one time a complete set of design blueprints, prototypes, and technical documents, rather than buying separate items. Although the cost is comparatively high, it will reduce the number of unanticipated difficulties encountered during the transition.

4. A broad range of information should be collected and everything understood thoroughly. Once done, then decisive action should be taken in finalizing a contract, so opportunities do not slip by.

Operation of town and township enterprises requires long-term planning. Do not be overanxious for results. Do not think that one can become fat by eating one mouthful of food. And do not think that one burst of effort will provide eternal ease, that one technical project will provide for a lifetime. The invention, development, and process of replacement of new technology must be mastered. "Have one in hand, one in the mouth, and one in sight." Only in this way can one seek to exist and expand in the midst of competition.

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FORMS OF PAYMENT FOR COMMERCIAL TECHNOLOGY DISCUSSED

Tianjin JISHU SHICHANG BAO in Chinese 1 Jul 86 p 4

[Article by Kong Huimin [1313 1979 2404]: "My Opinion Concerning Pricing and Forms of Payment for Commercial Technology"]

[Text] The opening of markets for technology and the commercialization of technical findings are new developments for China. There are many related problems that should be studied. Among them, the problems of pricing and forms of payment for commercial technology have still not drawn much attention.

In technology markets, generally there are three forms of payment for technical findings: 1) One flat calculation. When the contract is signed, the use fees for technical findings are calculated once. The total can be paid completely or it can be paid in installments. 2) Percentage payment. After the technology is adopted, a set percentage fee is paid on the basis of production or profits. 3) Retainer fee plus percentage fee. First, a retainer fee is paid, then in successive years a percentage is paid based on production or profits. At present, in the technology markets of Tianjin Municipality, the first form of payment is used in the majority of cases. The reasons are: 1) Among the technical findings that are transferred in the technology markets, most involve minor inventions in new areas. Prices are relatively low, and purchasers generally are able to pay the flat fee. 2) When using this form of payment, the seller has the least responsibility. As soon as the goods change hands, the seller has no further responsibility concerning the applied effectiveness of the commercial technology. Therefore, the seller commonly is willing to accept this form of payment and pricing. 3) This form of payment is simple. But it should be noticed that this is because this form of payment means that when the commercial technology is used there usually is no further tie between the economic benefits that are produced and the seller of the commercial technology. The price of the commercial technology is set by one round of talks and negotiation and is not tested by actual practice. This weakens to a certain extent the degree to which the seller of commercial technology feels responsible for the effectiveness of the technology when applied. At the same time, this is also an undesirable trend in the technology markets. For example, individual units lack a commitment to service and blindly seek profits. A very small number of them transfer immature or false technology, hurting others to benefit themselves. Of course, this is related to the imperfect nature of management of technology markets.

The adoption of the retainer fee plus percentage form of payment goes a long way toward eliminating the abuses mentioned above. It also helps spur S&T to better serve production. 1) During the transfer of commercial technology, the payment first of a retainer fee helps compensate the technology seller for some of the expenses that were incurred. 2) The percentage payment links the income of the seller to the economic results obtained when the technical findings are used by the buyer. This creates some pressure for the seller to take responsibility for particular new technologies and methods. It also provides a motive related to his own economic self-interest. From another viewpoint, this method further spurs the inventors of commercial technology to discover new problems during the course of applying the new technology, then improving it and creating new technical findings. This helps form technical findings into systems.

At present, the use of retainer fee plus percentage fee is not the most frequently used form of payment in the technology markets of Tianjin. There are many reasons for this, including the level of prices and technical standards in commercial technology. It also is related to the degree of trust between the two parties in trading and insufficient informational work.

Therefore, the following problems now should receive attention:

I. Retainer fee problems. Retainer fees are set solely by the two parties involved in negotiation. With differences in the commercial technology, there can be differences in retainer fees that are set. It is difficult to set a definite formula for retainer fees. The fee should serve as a way the purchaser of commercial technology guarantees the contract and demonstrates it will be fulfilled. It also is advance payment given to the seller of the commercial technology. It is a proper form of economic compensation for the direct embodied labor and living labor costs incurred during the process of creating the commercial technology. It takes the form of a set monetary value. The retainer fee is paid before the commercial technology is used regularly by the purchaser, and the estimated economic returns have not yet been realized. Therefore, the retainer fee cannot be excessively high, and should not be excessively high.

II. Percentage fee problems. The amount of the percentage fee is directly related to the material interests of both the owner of the commercial technology and the user. This fee takes the concrete form of being a relative percentage between seller and buyer based on succeeding years of production and profits. Commercial technology is a good that tends to be monopolistic or exclusive. Therefore, the amount of socially necessary labor time expended in creating the commercial technology is poorly and incompletely revealed. This labor time also cannot be the source of price movements for commercial technology. Therefore, the price of commercial technology is determined by negotiation between the two sides in a contract. The degree to which the percentage fee is met also is the degree to which the price of commercial technology is fully realized. The principles used in setting the amount of percentage are as follows: 1) Protect the interests of the seller of commercial technology. If the monopolistic price of commercial technology is to be realized, there must be full consideration given to estimating the degree of complexity in producing the commercial technology, and the long-term nature of the labor involved (including the accumulation of knowledge). This should not be underestimated. 2) The interests of the buyer of commercial technology provides material conditions for increasing production and profits, the realization of production or profits beyond the state quotas is due to the labor of ministries involved in material production. Therefore, the level of percentage fee paid cannot exceed the complete or majority of profits earned on goods produced over quota.

III. Organization problems. To set up specialized organizational structures or staff, there should be scientific evaluation of the technical findings that are in the technology markets and their economic implications. This will insure that the material interests of both parties will be reasonably realized. Now when the prices in the technology markets are adjusted by the market, the state's macroeconomic management of the technology markets obviously is very important.

IV. Strengthen research. At present, the problems in pricing and forms of payment in the commercial technology markets should be conscientiously studied. First, this would help both sides that are involved in technology trade choose the best form of payment. Second, it would help expand popular awareness of the pricing and forms of payment for commercial technology, which would aid the healthy expansion of the technology markets.

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NATIONAL DEVELOPMENTS

LIAONING PEOPLE'S CONGRESS PLENUM HEARS REPORT ON SCIENCE POLICY

SK201140 Shenyang Liaoning Provincial Service in Mandarin 2200 GMT 19 Sep 86

[Text] The 22th Standing Committee meeting of the 6th Provincial People's Congress held the 3d plenary session on the morning of 19 September. The session heard a report on the situation of the scientific and technological restructuring delivered by Ji Zhong, chairman of the provincial scientific and technological commission.

In his report, Ji Zhong said: The fighting goal for the scientific and technological restructuring in the future is to strive to preliminarily establish within 5 years a scientific and technological system with vitality, where organizational structure and operation mechanism are comparatively reasonable, and where science, technology, and the economic construction are closely linked.

The governments will shift the focus of scientific and technological management from direct control to indirect control, since the scientific research units are given flexibility in management and possess stronger capabilities for self-existence and development. Technological development research units should economically rely on themselves by gradually withdrawing operating expenses. Most of the technological development research units should be changed into development research associations with decision-making power, while the rest should be changed into scientific and technological development departments of the enterprises by combining themselves with enterprise groups and integrated enterprises. The scientific and technological findings should be sent out through market channels in line with the law of the commodity economy. To realize this goal, from now on, we should continue to grasp the reform work in five fields, such as reforming the appropriation system, commercializing technological findings, conducting lateral cooperation between scientific research and production, reforming the system of managing scientific and technological personnel, and expanding the decision-making power of the scientific research units. Simultaneously we should strengthen macroeconomic management; achieve scientific and technological legislation; tackle scientific and technological problems; organize forces to implement the spark plan and the plan for building 100 scientific and technological model villages, 20 scientific and technological model townships, and 3 scientific and technological model counties throughout the province; further implement the open policy; enthusiastically conduct scientific and technological cooperation and exchanges with foreign countries; achieve the work of exporting technologies to other places; and strengthen the research on soft science.

/7358
CSO: 4008/5

NATIONAL DEVELOPMENTS

REFORM OF SCIENCE, TECHNOLOGY COMMISSIONS DISCUSSED

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENCE OF SCIENCE AND MANAGEMENT OF S&T] in Chinese No 7, 12 Jul 86 pp 30-32

[Article by Ren Zhenjiang [0117 2182 3068], Yu Tainian [5713 3141 1628] and Wang Liwen [3769 0448 2429], of the Tianjin Municipal Science of Science Institute: "On the Strategic Shift of the Work of the Science and Technology Commissions"]

[Text] To keep pace with the structural economic reform, the reform of the science and technology system must be quickened. As the functional organizations in charge of science and technology work under government departments at various levels, the science and technology commissions should readjust their orientations, redesign their work and goals, set up suitable organizational structures, change their staffing patterns and improve the quality of their cadres. These are the things which urgently need to be done in order to speed up the reform of the science and technology system. A new strategic shift is to be made in the work of the science and technology commissions.

New Orientation, Scientific Goals

People refer to the science and technology commissions as "project commissions," which is an apt description of the commissions' work in the past and also points out sharply the crucial reason for the commissions' failure to adapt their work to the demands of the current situation. For a long time, the commissions have tended to concentrate more on managing specific projects than on giving overall guidance. As a result, the number of projects and plans has multiplied; the administrative structure has grown increasingly cumbersome; personnel have increased steadily; and funds have always been insufficient. Like invisible ropes, the "projects" wrap around the departments. They have formed a powerful inertia, affecting people's activities, work style and even way of thinking. The commissions are tied up by "projects," and fail to fulfill many of their essential responsibilities. While they fail to provide concrete guidance, units at the grassroots level can only wait passively and cannot give play to their own initiative and vigor. The inability of the commissions to take care of the important things has inevitably weakened their effectiveness as government organizations. It is also one of the causes for the growth of bureaucratism.

The development of science in breadth and depth is accompanied by a division of research into highly specialized disciplines and, at the same time, an obvious trend toward synthetic studies. A deep understanding of this important characteristic of modern scientific and technological development should give us useful guidance in readjusting the work and goals of the science and technology commissions. What the science and technology management departments have to deal with is modern science and technology, which they should analyze and synthesize continuously to enter a stage of "omnidirectional" comprehensive study of all disciplines at all levels and of the vertical and horizontal relations and cross effects between them. At the same time, China's scientific and technological establishments today are also beyond compare with what they were in the early period following the founding of the People's Republic, and their growth is being more and more closely coordinated with economic and social development, which shows their important role in the four modernizations drive. Obviously the work for which the science and technology management departments are responsible has changed a great deal in depth and in scope, and if they still concern themselves with running a few projects and getting their share of operating funds as they did in those early days (even though it was necessary and useful for them to do so then), they will fall far short of what they should do. No matter how many projects they can take care of, many more are bound to be left out. In reviewing and summing up their own work, they will have little to report other than the projects they have worked on. Therefore, others are also uncertain of the role of scientific and technological work.

From the course of its development, wecan see that the idea of science and technology management has developed from one of standardization in the 1920's to one of systematization today, or from a mainly analytical era to a mainly synthetic era. Systems management is characterized by its grasp and use of the information of an entire system. Therefore, information and control are the two essential factors of systems management.

In veiw of this, in readjusting and planning their work and goals, the science and technology commissions at all levels must first of all free themselves from the pattern of "project commissions" and reverse the whole set of traditional work habits, forms of activities and ways of thinking formed under the long influence of this pattern. Second, to really give play to their administrative functions as government organizations, the commissions must shift their administrative functions as government organizations, the commissions must shift their attention from specific projects to macroscopic guidance and overall control. Each science and technology commission must have a clear understanding of the tasks assigned to it by the system to which it belongs and do what it is supposed to do, not what should be done by other departments. Under no circumstance should it compete with others to do what others should do. In other words, it should "do the right things," and not "do things right." Otherwise, it is bound to adversely affect the effectiveness of the whole system. Third, it is necessary to separate government from enterprise and administration from research, streamline administration and give more power to lower units. The science and technology commissions should neither engage in many projects nor directly run many centers. Only by giving up these entities can they become relatively "detached" and be able to concentrate their attention on studying and formulating principles and policies, scientific and technical legislation and enactment of rules and regulations, strengthen their supervision and inspection functions, and play their role in organizing, coordinating and achieving an overall balance in scientific and technological activities of overall importance, such as activities of the research and development departments, the scientific and technological services departments, international cooperation, major research projects, the opening and control of science and technology markets and so forth. The more decentralized it is in getting things done, the more necessary it becomes to strengthen centralized control. Only from a commanding height is it possible to press on irresistibly. Fourth, the emphasis should be shifted from "hard items" to "soft technology." Only through the study and formulation of principles and policies, rules and regulations, plans and programs, and strategies and tactics, will it be possible to strengthen macroscopic guidance and overall control. If we put the emphasis only on hard equipment and ignore soft technology, it is impossible to put the equipment to good use. It is like a man with body but no soul, who is at best an imbecile. Research projects on soft technology should occupy an increasingly important place in the work of science and technology commissions. Expansion of soft scientific research is an important guarantee and way for achieving the commissions' goals. It is also the only way for the science and technology management departments at various levels to become the "nerve center" for the scientific and technical activities under their jurisdiction, and the "overall planning department" for scientific and technological work. Quick access to information and effective macroscopic control are the two most important signs of their effectiveness, and information is the indispensable prerequisite for control.

Suitable Organization and Modern Management System

What organizations to set up, or not to set up, and how they should be structured should be determined mainly by a department's work and goals. High goals cannot be achieved without superior organization.

Although the organizational structure of scientific and technology commissions has been readjusted several times, merging, dividing, growing or shrinking, on the whole, it is still built around the "project-oriented" general guiding principle. For example, on the basis of project fields are formed the industry department, agriculture department, new technology office, new materials office and so forth; or on the basis of research procedures, there are the planning department which approves and finances project proposals, the key projects organization and coordination department, the achievements department which handles matters in the later stage of projects, the technology transfer office and so forth. Even departments in charge of long- and medium-term planning put the stress mainly on hard technological projects. The result is numerous grassroots research units revolving around the government, vying with each other to start research projects and get funds. The organization as a whole is "bustling with activities," and every department feels gratified and proud for its own "indispensability" and "importance."

As new projects keep coming up, more and more new organizations are set up, and they keep growing and become overstaffed. Obviously it is imperative to streamline administration and give more power to units at the grassroots level in accordance with the principle of "simplification, efficiency and opposition to bureaucratism." In the past, people often associated "streamlined administration" with smaller organizations and fewer employees, the smaller and fewer, the better, as though a smaller organization is always better than a larger one. In fact, the idea is no longer applicable in this era of complex large systems. In today's world, administrative structures are changing rapidly, some shrinking, others expanding and still others being set up for the first time. All this is a reflection of the requirements of objective development. For example, in various countries, think tanks--soft science organizations, various kinds of information centers, strategic research organizations and consultation systems for entire societies--are continuing to develop. Therefore, organizations should be set up mainly according to needs. Some should be smaller and simpler, and other should be larger and more complex. On this, we cannot demand uniformity. When "simplification" is called for, we must not always cut back on the so-called "soft" departments, the result of which is not just a smaller organization but lower capability.

We hold that in planning for better organizations at present, special emphasis should be placed on strengthening the macro-strategic research organizations, which put together the work of forecasting, better decision-making, intelligence and information, policy makeup, laws and regulations, systems analysis, technical and economic analysis, technical appraisal and so forth to become unified research entities and to serve as brain trust and consultative bodies for the science and technology commissions. Their major task is to put forward meaningful advisory reports in good time on matters of overall importance and keep putting forward various kinds of plans for the leadership to choose from either on their own initiative or at the leadership's requests, thus playing a good advisory role in promoting scientific and technological development.

A sound functional organization must have three component parts: a policy-making body, an executive body and a brain trust. The times are gone when one or a few individuals could run things on their own experience and judgment and succeed. Narrow and limited experience and rash decisions cannot produce scientific management. The so-called scientific management is essentially the extent to which management has reduced, even eliminated, its dependence on experience. In the present management system, the previously mentioned three functions are still in a mixed and unsettled state, as they have not been separated organizationally. Inevitably the leaders not only must make the decisions but have to conduct investigations and consider plans, and when decisions are made, they must take part in their implementation. The situation is known as "self-planning and self-implementation." In the meantime, no one provides them with what are really needed: data, facts, condition analysis, development trend forecast, policies and measures which may have a bearing on the development trend, and results of simulated tests. Unless an end is put to this state of affairs, it is impossible to change the backwardness of the work of the organizations, characterized by passivity, confusion, wasted effort and low efficiency.

The Key Lies in Having Competent People, Improving Personnel Structure and Cadre Quality

Higher goals and better organizations depend ultimately on intelligent people. If we fail to make conscious efforts to change the personnel structure and improve significantly the quality of cadres, improvement of the operations of the entire system is nothing but idle talk.

The greatest difficulty here is to set people free from the ideological shackles of the traditional "project commissions" and turn their vision from specific projects to the new goals of management. Some people hold that it is right and proper for the science and technology commissions to focus their attention on research projects. "If not concentrating on research projects, what should they do?" "If they are to concentrate only on making policies, forecasting future developments and devising strategies, which amount to little more than empty talk, what practical problems can they solve?" Some people ask, "If you have nothing practical to offer, who will listen to you?" Remarks like these reflect the strong feelings of some people about "projects," and it will take some doing to convince them of their mistake. But, as one economist has said, "At present, we have to set our sights low. We can pursue medium-range economic goals at most, and tackle only small problems, like selling longan and counting flies. We need to study an X method, which requires information, data, electronic computers, terminals and graphic work." This method is systems engineering. It is a technology of organization and management in a modern society. Its potential for practical applications in all aspects of social life is undoubtedly tremendous. To keep pace with it, people must have a synthetical mind, systematic viewpoint, strategic foresight, policy concept and statistical sense. This is a major broken link in people's thinking and understanding, and it is an extremely arduous task to fill the gap.

To change the intellectual makeup of organizations, it is necessary to increase the proportion of technicians specializing in systems analysis, information processing, policy simulation and other professional work and the proportion of economists, designers and engineers. It is necessary to reduce the overlapping of specialties and change the situation in which "everyone is in charge, but no one knows what to do."

We should remember the lessons in the history of the development of mankind. There are times when the productive forces and way of life have to change, and nations or countries which are unwilling to accept the change and stick to the old ways will not be able to stand tall among the nations of the world. The nations which failed to adapt to the change from hunting to animal husbandry or from gathering wild fruits to crop farming have largely perished long ago. The nations which failed to keep pace with the industrial revolution have long suffered from their backwardness and from aggression. In this age of rapid scientific and technological progress, we should redouble our efforts to promote the cause of reform. In organizing the people to march forward toward modernization, we should first of all raise the scientific level of our own work.

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NATIONAL DEVELOPMENTS

SUMMARY OF 2D INTERNATIONAL S&T POLICY SYMPOSIUM

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENCE OF SCIENCE AND MANAGEMENT OF S&T] in Chinese No 6, Jun 86, p 45

[Article by Xu Chaoqian [4958 6389 0467]: "Summary of 2d International S&T Symposium"]

[Text] Following the first international S&T symposium in Beijing in 1983, under the support of permier Zhao Ziyang, the second international S&T symposium took place on the 7 April 1986 in Beijing. Among the attendees there were 40 specialists from other countries and 20 from China. Song Jian [1345 0256], minister in charge of the State Science and Technology Commission, pointed out in the symposium, that the developing countries must formulate policies to utilize human and material sources reasonably. He thought that the "spark plan" formulated by the Chinese to stimulate the local economy and rural enterprises and the high-tech development plans are policies which use S&T to promote economic development. During the symposium, specialists were received by the premier. The concrete conditions in China, Japan and Korea were used as reference in the symposium and the following aspects were discussed:

1. Function of State in Giving Full Play to Latent Power of S&T

Judged by the developing countries, China has offered a suggestion on policy in this aspect, which transfers the S&T results from the research departments to production departments, from military use to civil use, from the prosperous coastal regions to the backward inland regions. Furthermore, S&T system reform has been started in China, which has manifested itself mainly in 1) formulation of the "spark plan", 2) commercialization of S&T results, 3) reform in financial allocation for S&T research, 4) reform in the management of human resources, and 5) strengthening the ties between S&T research and production departments. The concrete measures adopted by the governments of Japan and South Korea are to stimulate high-tech development such as electronic technology and biotechnology, and implementation of a tax policy to promote high technology to create good conditions for technological innovations.

The symposium deems that each country should select appropriate technology which is consistent with the social and economic goals of that country, combine new technology with traditional techniques and make them match.

In addition, the government must formulate different development strategies for the various professions and make strategic choices, such as the selection between the two strategies of replacing exports with imports and the combination of the two. The government should also formulate strategy for educational system development and strengthen the ties among S&T developments, industrial departments and the government.

2. More Effective Utilization of Technological Talent

Planned education and talent cultivation with a goal are more beneficial for the realization of the state plan than blind education. Talent education is an important way to realize the state plan. In addition, developing countries should pay full attention to the traditional wealth of knowledge and provide the masses with normal education.

The symposium points out the importance of basic facility development for the policy research mechanisms and the importance of strengthening the ties among colleges, universities, S&T research units and industrial departments. The specialists put great stress on the utilization of human resources, including the training of personnel who can make intermediate and long term assessments and decisions. The decision makers in state planning, and industrial development in every country, should have a better understanding about the utilization of the latent power of S&T personnel, that technology development must have a period of risk, and is the product of a series of overall social and economic strategic plans, and that it is the state that must implement the necessary policies and measures to promote technology development. Among the developing countries, the following problems should be solved: 1) Establishing effective mechanisms and systems to promote technology development, 2) Establishing the mechanism and system for technological result transformation, and 3) Establishing the mechanisms and systems to use human resources effectively.

The specialists thought there should be cooperation between countries and between S&T research units in different countries, to launch dialogues regionally and with other regions to exchange information and to strengthen the technology force of the developing countries. In countries with large populations, they need to pay great attention to formulate plant to encourage personnel development while encouraging modern science study, strengthening basic education and vocational education and planning university education according to reasonable economic goals.

Technology development entails difficult activities; successful technology development comes from healthy management systems; developing countries must intensify their training of management cadres. S&T information system and S&T service must synchonize with research and development, in order to strengthen and update the knowledge of the people and stabilize research and development.

3. Link University Reserach Institutes With Production Departments

The necessary measures taken by China is to provide the research institutes with full authority for the transfer of technology results, to promote direct contact between research units and production units, improve the price system unfavorable to new technology development and to dredge the various capital channels.

Developing countries find that in encouraging contact between institutes and production departments, they need to solve the conflict between the single discipline structure and planned research using many disciplines. Universities, design institutes, engineering colleges and production departments are all engaged in S&T research; individual department research is important, yet cooperative research can bring greater results for the economic development of the state. Whether in the developed or developing countries, integration of university research institutes with various design institutes can often produce new technology.

Effective integration not only requires systematic methods but also mutual targets for the cooperation of the various districts at the very beginning, and a good environment for cooperation.

4. Utilizing Capital from All Channels to Promote S&T Development

Regarding capital, China established the contract system and the capital mechanism management system, and risk investment as one kind of channel for capital; owing to the nonexistence of a currency market in China, a special form of market took shape, and risk investment has become the bridge that links S&T development, production and markets, and has become the guide for workers and enterpreneurs to develop toward the economic goal. To promote her economy, Brazil's government adopted the low interest plan and conditional financial plan to provide risk investment and noncompensation loans. In taxation, a commission is allowed for enterprises in their capital spending and depreciation of fixed assets and intangible assets to spur enterprises to adopt new technology.

It is very important for all states to encourage the local governments to invest in research and development, such as supporting research and development with low interest, providing financial support for the invention of research and development enterprises, to encourage risk investment, and to encourage the establishment of new invention companies with capital, etc.

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NATIONAL DEVELOPMENTS

PILOT NEW TECHNOLOGY DEVELOPMENT ZONE OPERATIONS

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENCE AND SCIENCE AND MANAGEMENT OF S&T] in Chinese No 6, Jun 86 p 34-35

[Article by Gu Wenxing [7357 2429 5281] and Zhou Liangyi [6650 5328 3015] from the Shanghai S&T Commission: "On Running a Pilot New Technology Development Zone"]

[Text] New things need to be handled with new methods. To run a pilot new technology development zone and its construction, we suggest that we adopt special policies and management. These policies involve raising capital and investment, introduction and digestion, bank credit, taxation, material sources, management, labor wages, and personnel management which can be generalized into the following five aspects:

1. Capital Raising and Investment. Where does the large amount of capital for new technology development come from? Many channels can be used to raise the capital, including the nation, foreign countries, the central or local government, enterprises, the state, individuals, the masses of the people and groups. There must be a specific purpose for the investment.

A. Establishment of new technology development risk investment foundations, called new technology development zone foundations. Money for this foundation comes mainly from the state in a special item of funding listed in the annual budget each fiscal year; part of the money comes from economic and science commissions which squeeze some money from their funds, and part comes from the other related departments and commissions. In addition, all the related banks and investment credit organizations can also provide some capital. According to the different situations, the investment can be noncompensation, part-compensation or compensation.

B. A new technology development foreign exchange foundation must be established to provide the amount of foreign exchange needed for the research and development of new technology. Part of the money for the foundation comes from the state, part from the local government, used for technology innovation, and part from the overhead of the local government, and part from loans from Bank of China, also including donations from overseas Chinese and foreign exchange from foreign investment.

C. Banks must establish loans for new technology development, with low interest or no interest; the interest shall be balanced by financial management.

D. New industrial stocks, bonds and development bonds must be issued to encourage the traditional industrial departments to invest in new technology development (including large and medium pilot projects).

E. In investment in research and development of new technology, intermediate experiments and its industrialization, we must choose the better ones, stick to our purpose, and the material, components, test instruments and test solutions must be a complete set in order to gain fast results.

Taxation

F. Pilot products of a new technology under intermediate experimentation should be tax exempt for a certain period of time. For factories doing intermediate experimentation without yet putting it into mass production, the number of new products manufactured, number of items transferred, and their quality should be checked as the main goal, and the target of output value and profit as the secondary goal.

G. For those factories doing demonstrations, a policy of planned loss and financial compensation within a certain period of time should be implemented.

H. Regarding new industry and enterprises, for a certain period of time, they should be exempted from the adjustment tax (including its new technology product equipment) and product tax, and their income tax should be reduced by half, and part of the energy and transportation construction funds submitted should be returned. The money saved from the exemption, reduction and returns should be transferred into the produciton development fund of the enterprise, new product development fund, or used for a reasonable price cut.

I. The number of years of depreciation of the equipment of new industry and enterprise shall be shortened one-forth to one-third according to present standards; depreciation charges submitted to the authorities according to the law, shall be totally returned to the enterprise to be used for renovation or modification funds.

J. In light of the comprehensiveness of the new industry and enterprises, their involvement in many administrative levels and the vastness of areas to cooperate, differentiated taxation shall be implemented for all of the new tech products of cooperative production.

Opening-up and Introduction

K. New technology development zones shall be allowed, within the limit of laws and regulations of the state, to take the initiative and independently engage in the introduction of technology, specialized personnel, joint ventures, international academic exchanges, collaborative research and export of new technology products, organize product exportation under the guiding policy of integration of industry and trade or technology and trade, and reserve a certain percentage of the foreign exchange earned, within a period of time, as a preferential act.

L. Open door preferential policy for the new technology development zones shall be formulated in reference to the related special policies of the special zones and the 14 open coastal cities to create a good environment, to attract great amounts of foreign capital, foreign technology and talent, to encourage Chinese and foreigners to cooperate in research, and joint ventures in the establishment and management of new industry and enterprise, to encourage Chinese to establish enterprises of this kind abroad; their investment shall be protected, and their income shall be retained for a period of time, and all the foreign exchange may be retained.

M. The target of the introduction of technology in the new technology department zones must be digestion, absorption and innovation. There must be specific policies in the formulation of the planning, approval of the items, capital arrangements, selection of the organization in charge, organizing personnel and the implementation of reward and punishment, to guide the people to put their attention and excitement on digestion, absorption and innovation.

N. During the open door period, limited protection for the new technology and its production in the country should be implemented. Certain kinds of gaps between the level of research, development and production in some of the new technologies and those of the same kinds in a foreign country, shall be allowed for a certain period of time; taxes should be adjusted; use of local technology products should be encouraged. Customs duties on imported industrial and commercial items should be raised for those technical products which can be produced up to international standards and can be supplied locally, in order to stimulate and promote the new local industry to mature and develop.

Attracting and Using the Talented

O. Recruiting, contracting, and visiting research systems should be implemented for all personnel in the development of new technology and those in the construction of the new technology development zones, to select and collect the finest people in every aspect, and put them in a dynamic situation to give optimal performance.

P. In the new technology development zones, all employees shall be paid according to their position, and their labor, promoted or granted a pay rise, and also receive preferential treatment in welfare benefits.

Q. Comprehensive lifelong education must be implemented for personnel of different types and levels in the new technology development zones, such as researchers, engineers, assistants, management personnel, technicians and service men.

Organization and Management

In regard to the organizational and management systems of this integrated complex, according to the difference in the level of the new technical development and the degree of industrialization, the following three different forms can be adopted accordingly:

The first is to organize a genuine specialized company. Companies whose research and development in new tech have reached a certain level, acquired a certain dimension in productivity, such as the computer business and the semiconductor business in Shanghai, but still are administrative in nature, should actively create conditions to be transferred into enterprises and economic entities. If the newly established integrated complex has the right conditions, it can be, at the very beginning, an enterprise and economic entity. Some factories and workshops producing products of the same type but scattered in different businesses or mingled with traditional industry, can also be picked out of the original business to form a specialized company.

The second is to organize a united company as an entity but loosely connected. In view of the practical situation in Shanghai, the most important is to organize this kind of company in great numbers. That is, when there is already a small entity or part of a factory, institute, college or school and it is time to organize an entity, then they can be united to let the entity be the principal part and maintain the original administrative relation and use the itemized tasks as a spur to organize a united company.

The third is to organize loosely united companies (technology development centers). New technology which does not belong to either of the two conditions mentioned above may be organized, according to the engineering items or products, specialization, and the requirements of the technical development, as a loosely integrated complex, which must have a principal unit to function as a backbone, connector and bridge. As for which one dominates, it depends; if the complex is in the S&T development stage, the institute will dominate to organize a S&T research and production complex, and when the S&T research and development reaches the intermediate test and production stage, the factory will dominate to organize a production and S&T research complex.

The various complexes are not immutable. Some can be gradually developed into an economic entity, some on the basis of loose connections, may be merged into research mechanisms from enterprises or into enterprises from research mechanisms; some research organizations may develop into S&T production or a technology development mechanism of united enterprises.

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NATIONAL DEVELOPMENTS

RESEARCH ZONES IN INTELLECTUALLY RICH AREAS DISCUSSED

Tianjin KEXUEXUE YU KEXUE JISHU GUANLI [SCIENCE OF SCIENCE AND MANAGEMENT OF S&T] in Chinese No 6, Jun 86 pp 30-32; 34-35; 45

[Article by Zhao Wenyuan [6392 2429 1750], Li Tieru [2621 6993 0320]: "On the Construction of Areas with Rich Intellectual Resources"]

[Text] I. Areas with Rich Intellectual Resources and New Industry

The term areas with rich intellectual resources does not refer to the general meaning of areas with intensive knowledge and concentrations of intellectuals; it refers to putting the universities, natural science research organizations and technological enterprises in the same area and establishing effective connections and cooperation to carry on high technology research, new industrial development and raise educational standards. In the past two decades, combined groups of this kind have been established in many countries, and various names are used, such as X X city of science, science park, research park, industrial park and so on. In the past decade, many countries have been competing to study and create areas with rich intellectual resources which have resulted in an "intellectual intensive area fad."

The emergence of this phenomenon is not accidental. With the development of modern S&T, "knowledge has become the key of productivity, competing forces, and economic accomplishment. Knowledge has become the most vital industry which provides the economy with necessary and important productive resources." Various industries based on science and develop rapidly; the hope to further raise productivity has been changed from mainly depending on natural resources and energy, to mainly relying on intellectual resources and S&T. So, it becomes an inexorable trend of the development of history to establish areas with rich intellectual resources and rely on that resource. From now on, intellectual intensive areas will become the symbol of new productivity of a society and the most important part of the social structure, based on preliminary statistics, there are more than 150 intellectual areas in the world. They have the following characteristics:

A. They engage mainly in intellectual work, including passing on knowledge, creating new knowledge, storing knowledge and utilize knowledge. Therefore, an intellectual intensive area is essentially an industrial area which produces knowledge.

B. An intellectual intensive zone helps to closely connect intellectual industry with social economic development to become a great force for social economic development, and provide a vast world for development of knowledge.

C. "Concentration of intellectuals." Scientists, engineers, and sociologists in various disciplines constitute the body of the intellectual intensive zone. Here the average education level of the personnel is 5 years elementary and 2 years technical education, and the number of scientists and engineers is 10-20 times higher than that of an industrial zone.

An intellectual intensive zone must be closely connected with a new industrial zone. The term new industry refers to the brand new industrial system established on the foundation of new product development. At present, the content of new industry includes, in addition to semiconductors and computers, bioengineering, new materials, space technology, photoelectric communications and oceanic engineering; all of which are to be industrialized. These new industries have in general, the following two characteristics:

i. They belong to the knowledge intensive industries and are advanced technological industry developed on the basis of modern scientific accomplishment. So, new industry is also referred to as high-tech industry.

ii. High-tech industry is originated in the intellectual intensive zone where S&T are retained; for example, American microelectronic industry is concentrated mainly in two districts; Silicon Valley in the West and the area along highway 128 in the East, Stanford Industrial Park and the University Park of MIT, are the two places of origin of the two new industry zones.

II. Requirements for the Establishment of an Intellectual Intensive Zone

1. The presence of universities with advanced colleges of science and technology, and research institutes of natural science. Why is the British "silicon valley" located in the vicinity of Cambridge but not Oxford? One of the reasons is that Cambridge university is superior in natural sciences. For example, the famous Cavandish laboratory in the physics department has been the world leader in molecular biology, radio astronomy and photoelectric analyses; Cambridge Scientific Instrument Corporation established by Horace Darwin, son of Charles Darwin in 1881 and the [Pie-E] Corporation which manufactures only experimental and educational equipment, are both well known. It is this superiority that attracted far-sighted entrepreneurs. In the past few years, high-tech industry emerged around Cambridge like bamboo shoots after a spring rain, so the place where the ancient seat of learning is situated became one of the zones in England, which are full of vitality with economic growth at the fastest pace, termed by the British people as the "Cambridge phenomena."

2. The Natural environment of an Intellectual intensive zone must be attractive. If all the other conditions are similar, the conditions of natural environment, weather, transportation, living standard, cultural and education level will be decisive factors in whether a zone will be attractive

to researchers. To prove this point, some people in the United States surveyed 40 researchers in order to discover the important factors that affect them in their choice of a place to live. The answers, in order of importance, are good weather, good schools for children, entertainment and recreation, low living cost (low tax), and good environment.

This investigation has universal significance to China and many countries in the world. Even in a country with a small territory, and even if their researchers have little choice in weather conditions, it will not work without the other factors.

3. The Establishment of an Effective Management System

The management system relying only on division of labor and separate departmental administration can no longer fit the construction of an intellectual intensive zone. A horizontally connected, cooperative and mutually administered new system must be established among the universities, S&T research organizations and enterprises. This mutually administered cooperative mechanism should possess certain administrative functions and some social liaison function similar to that of a people's organization. The principal leadership of this mechanism must be a prestigous person whose influence should be greater than the administrative power he has, and he (she) should be able to speak "two kinds of languages," that is, be able to supervise the work of both the scientists and the industrial workers.

4. The availability of venture capital. An intellectual intensive zone can only provide talented people and high-tech for the development of the new industry; whether these talented people and high-tech can become an industry mainly depends on the availability of enough venture capital. High-tech industry requires not only technology intensity but also capital intensity. The American Silicon Valley is an important arena for the activities of U.S. venture capital, where one-third of the largest venture capital corporations have established offices; and the development of Highway 128 ahs something to do with the availability of enough venture capital in the Boston area.

Most of the countries adopt two measures to attract risk capital: 1) Encouraging states, groups and individuals to invest; and 2) Cutting taxes on risk capital.

III. Accelerating the Establishment of the Chinese Intellectual Intensive Zones.

The Chinese cultural and educational zones--the embryos of intellectual intensive zones.

In the mid fifties, when our country started to do urban planning and city construction, in Beijing, Tianjin, Wuhan, Xian, Changdu, Changchun and the other cities, some science, culture and education areas were established to put universities, research organizations and part of the cultural departments together in a certain area in the city. Doing this then was just a consideration of the overall arrangement of the city to facilitate urban management without any consideration about the connection between the construction of cultural and educational areas and economic development. After 30 years, these cultural and educational areas have all been established with considerable dimensions.

For example, the Zhongguancun district in the western suburb of Beijing, has become an area concentrated with universities and research organizations where the level of knowledge intensity can be matched by few in the world. In this 80 sq k area, there are put together more than 40 research institutes from the Chinese Academy of Sciences and the Chinese Academy of Agricultural Science, which have nearly 2,000 researchers. Most of the research institutes have a history of more than 30 years; experienced S&T researchers, a complete set of technology, good equipment, wide international friendship, a thousand research topics and several hundred items of research results, they have made great contributions to the economic development of the country and the national defense. There are situated 27 schools of higher education such as the famous Beijing University, Qinghua University, Beijing Polytechnic University, Beijing Normal University, People's University, Beijing University of Iron and Steel Technology, Beijing College of Medicine and Peking College of Navigation, with nearly 20,000 teachers, 60,000 resident students (including graduates) and a thousand disciplines.

Another example is the Donghu district in Wuhan municipality, Hubei province, where the knowledge intensity is next only to the Zhongguancun district in Beijing and occupies the second place in the country. In this 91 sq k area, there are 19 schools of higher education, such as Wuhan University, Central China Engineering College, Wuhan Institute of Water Conservancy and Hydroelectric Power, Wuhan Institute of Geology, Wuhan Institute of Construction Materials, Wuhan Institute of Geodesy, Photogrammetry and Cartography, and the Central China Agriculture college. There are 245 disciplines in these schools. Thickly dotted in the Donghu district are 54 S&T research and design organizations. Around these universities and research organizations there have been established a bunch of new factories and some backbone enterprises of the state.

In addition, culture and education zones such as those in Lanzhou, Tianjin, Shanghai, Changchun, Shenyang, Chengdu, Guangzhou and Xian, also have reached considerable dimensions.

Compared with those in the other countries, the culture and education zones in our country, can only be called embryos of intellectual intensive zones, and are not genuine intellectual intensive zones. The reason is that though universities and research organizations are concentrated in the areas and the knowledgee intensity is high, they are not really open to the society and have made little contribution to economic development and development of new industry; there have been no presentable high-tech enterprises established in the vicinity; the mechanism is not sound and lacks the social function to rapidly turn S&T to industry.

Our culture and education zones were established almost the same time as the rise of the foreign intellectual intensive zones, and some of our zones have good conditions, but why haven't our culture and education zones be developed into intellectual intensive zones? Generally speaking it was decided by the development of our productivity. Besides, the following points are also very important:

1. The influence of the "leftist" ideological yoke for a long period of time. For a long time we refused to acknowledge a basic issue that "knowledge is productivity" and we thought knowledge a superstructure belonging to the spiritual realm thus essentially denying the social and economic value of knowledge. In policy, intellectuals were pushed aside, the enthusiasm of the mass of S&T personnel was shattered which resulted in a poor attitude of despising knowledge and S&T, which resulted in the antagonism between S&T and productivity. In the economy, S&T research and education funds were mistakenly listed as state administration consumption funds, which indirectly blocked the investment of the enterprise in S&T research. Nevertheless, since the later fifties most of the countries in the world have started to list S&T research funds as production funds.

2. The structure of the system, owing to stress in the vertical administrative management system, resulted in departmental separatism; in education, a great wall was erected between S&T research and production, which worsens the ties among education, S&T research and production. There is little contact with each other among universities and institutes in the same area, and even among people of different disciplines in the same department; there was no circulation of the personnel whose knowledge was aging with duplicated research topics; the results of their research ended up as samples, scraps or gifts and could not be promoted for practical use in timely fashion.

3. For a long time, no relevant policy has been formulated in our country to support intellectual development, encourage teaching, and combine S&T research with production, such as letting S&T personnel and teachers take part-time jobs, compensation transfer of tech-research results, letting S&T personnel start new industries, and the lack of basic protection and due support in policy, law, tax, credit and public opinion.

4. The enterprises were run entirely by the state which lacks the vitality of competition; there was no change in the production mechanism in the past decades and the enterprise depended mainly on the increase of human resources and equipment, and some extensive methods such as "reproduction"; there was little enthusiasm to adopt new technology and the ability to absorb and digest new technologies was weak.

Since the party put forward clearly the policy that S&T must face economic construction and economic construction must rely on S&T, and the tie between S&T and the economy must be strengthened, especially after S&T system reform, S&T and economic development have entered a new era.

In order to promote S&T in our country to be a great force to speed economic development, we think that on the one hand, we must face the world, introduce and digest foreign advanced technology with enthusiasm, to shorten our research cycle to gain greater research results, change as soon as possible the structure of our industry to catch up step by step with the world; on the other hand, we must tap the latent power of the S&T available in our own country. The S&T force in the 10 culture and education zones occupies half of the S&T forces in the country, and it is an important topic to mobilize the S&T force in these zones to give full play to the precious S&T accumulated in the past 30 years in the construction of the four modernizations. The state should regard the work of tech development in these zones as a strategic mission to be listed in the overall planning; under the support from the state, not only may these zones become natural science comprehensive research centers and the best intellectual intensive districts, but also a bunch of high-tech enterprise groups with Chinese characteristics can be established, to spur on and promote the level of technology in the country, in the research and produciton of semiconductors, the development of computer hardware and software, large precision electronic instrument and test equipment, new material and the development of bioengineering technology; in these areas, universities and S&T organizations must be open to the society, a new system of mixing teaching, S&T research and industry must be established; we must learn from experience in the construction of the economic zones to establish the S&T special zones, visiting professor chairs must be established in the universities and the S&T organizations and allow S&T personnel to take part time jobs, encourage S&T personnel, especially middle-aged S&T personnel, to utilize their specialty to engage in business in technology development; and teaching must be encouraged, and S&T personnel accept, as an individual or a group, contracts from the state to start factories or enterprises; digesting introduced technology, engaging in technical consultation or technical training etc., must be encouraged.

It is on this foundation we will realize the transformation from a culture and education zone to an intellectual intensive zone.

In the past year, in the Zhongguan district in Beijing, the Donghu district in Wuhan, in Shipai in Guangzhou, in Jiading County in Shanghai [municipality] and in Nankai in Tianjin, under the guidance of the spirit of economic, S&T and education system reform from the state, they are changing from a culture and education zone to an intellectual intensive zone; just in Zhongguan district in Beijing, there have been established a couple of dozen companies and enterprises and there has emerged an outstanding street of electronics. China is a great country with one billion people, with great differences between districts, with complicated natural conditions, and we must establish according to the different situations, several or several dozen Chinese intellectual intensive zones with different characteristics.

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PHYSICAL SCIENCES

NEW NEUTRON-INDUCED IR ABSORPTION PEAKS IN SINGLE CRYSTAL SILICON

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 7, No 3, May 86 pp 334-336

[Article by Qi Mingwei [4359 2494 4850], Shi Tiansheng [2457 1131 3932], Bai Guoren [4101 0948 0088], Xie Leiming [6200 7191 7686], and Cai Peixin [5591 1014 2450] of Shanghai Institute of Metallurgy, Chinese Academy of Sciences, and Gao Jijin [7559 7162 6855] and Li Shiling [2621 4258 1545] of Institute of Atomic Energy, Chinese Academy of Sciences: "A New Set of Radiation-Induced IR Absorption Bands in Neutron-Irradiated FZ Si"; manuscript received 22 October 1985; first paragraph is source supplied abstract]

[Text] Abstract: In N-type neutron-irradiated FZ silicon, a new series of unreported absorption bands was discovered on the low frequency side of the divacancy related 2770 cm^{-1} peak. The characteristics and the annealing behavior of this set of absorption bands are investigated.

In the irradiation of n-type FZ single crystal silicon with a low dosage of neutron, a new set of absorption bands was found in the low frequency side of the 2770 cm^{-1} (3.61 μm) absorption peak which is related to divacancy (V_2^-). The preliminary results on the properties and annealing behavior of these bands are briefly described.

⟨111⟩ n-type FZ single crystal silicon specimens grown in different atmospheres (hydrogen, argon) were prepared. The resistivity is greater than 400 Ω-cm. They were cut into 5 mm thick wafers, polished on both sides and irradiated by neutron in a light water reactor. The radiation dose was 3.6×10^{17} neutrons/cm^2. The cadmium ratio is 10:1. Specimen temperature was maintained at ~40°C during irradiation.

All absorption measurements were made with a NiC-7199C FTIR spectrophotometer at low temperature. A miniature cooling circulator was used to cool the specimen down to the required temperature for about 10 minutes before a measurement was taken.

In all the low temperature (10K) infrared spectra of the neutron-irradiated specimens we observed two bands associated with the divacancy (V_2^-); i.e., 2890 cm^{-1} (3.45 μm) and 2770 cm^{-1} (3.61 μm). In addition, a new series of absorption bands was found on the low frequency side of the 2770 cm^{-1} peak, as shown in Figure 1. They are located at 2708, 2693, 2688, 2679, 2644 and 2634 cm^{-1}, respectively. However, the absorbance is approximately two orders of magnitude less than that of the peak at 2770 cm^{-1}. In the literature[1-4], although both bands at 2890 and 2770 cm^{-1} were detected, it was a flat base line on the low frequency side of the 2770 cm^{-1} band. This indicates that the sensitivity of their instruments was so low that this set of bands were buried in noise. Because these new bands are shown in all neutron-irradiated samples, the possibility that they are related to hydrogen is eliminated.

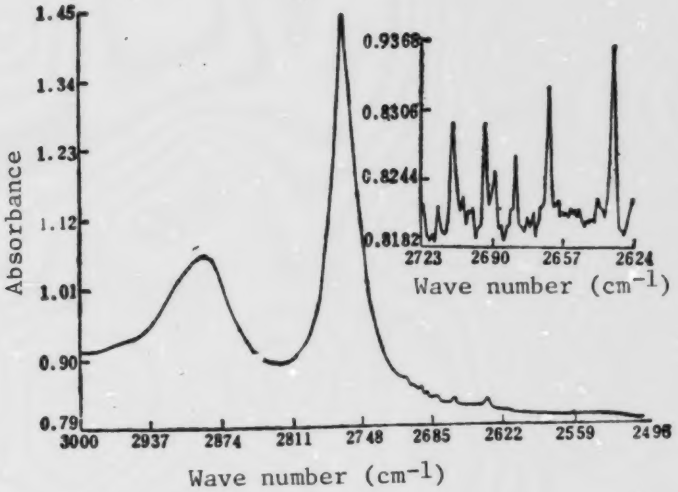


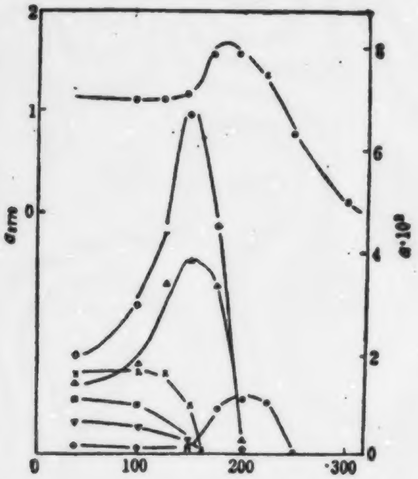
Figure 1. Infrared Spectrum of Neutron-Irradiated Specimen at Low Temperature (10K). Picture on the upper right corner shows a magnified spectrum of the new set of absorption bands.

2. New Electron Transition Bands

It has been confirmed that the absorption bands at 2890 and 2770 cm^{-1} are electron transition peaks at below 150 K[5]. We determined the temperature dependence of this new set of peaks and found that they were present only at below 50 K. As temperature decreases from 50 to 10 K, the intensity of these bands gradually increases. Their half widths and frequency positions, however, remain unchanged. This shows that these new bands are electron transition bands in nature, similar to those at 2890 and 2770 cm^{-1}. The half widths of the 2890 and 2770 cm^{-1} peaks were measured to be 52 and 22 cm^{-1}, respectively. However, the half width of the new band is typically ~2 cm^{-1}. This indicates that this new set of bands originates from a different defect center than the divacancy. In specimens irradiated under similar conditions, the intensities at 2890 and 2770 cm^{-1} are close for all samples. However, there are significant differences in intensity among this new set of bands. This suggests that they may be related to impurities in silicon. It appears that they are electron transition bands induced by neutron-induced defects or defect-impurity complexes.

3. Annealing Behavior

For comparison, the annealing behavior of the absorption band at 2770 cm^{-1} and that of this new set of bands are shown in Figure 2.



Annealing temperature (°C)

Figure 2. Annealing Behavior of Divacancy Band (2270 cm^{-1}) and 6 New Absorption Bands

○ 2770cm^{-1}, × 2708cm^{-1}, △ 2693cm^{-1}
▽ 2688cm^{-1}, □ 2679cm^{-1}, ◇ 2664 cm^{-1} ● 2634cm^{-1}

Based on the figure, the annealing temperature of the 2770 cm^{-1} band is $\gtrsim$300°C. The annealing temperature of these new bands is far less than 300°C. Again, it indicates that they are different from the divacancy bands. At least, they are different from the state corresponding to the 2770 cm^{-1} band. In addition, their annealing characteristics are not consistent. For instance, the three bands at 2708, 2688 and 2679 cm^{-1} decrease monotonically with increasing annealing temperature and disappear at 150-175°C, while the two bands at 2693 and 2664 cm^{-1} increase in intensity with rising annealing temperature. After reaching a peak at 150-175°C, they fall rapidly and disappear at 200°C. The band at 2634 cm^{-1}, however, initially remains unchanged with rising annealing temperature. It begins to grow at 150°C. After reaching a peak at 200°C, it begins to fall until it disappears at 250°C. Based on the above fact, these new bands can be divided into three groups; i.e., 2708, 2688 and 2679 cm^{-1} bands as group 1, 2693 and 2664 cm^{-1} bands as group 2, and 2634 cm^{-1} band as group 3. There is a certain transformation relation among the three groups, indicating that they represent different defect centers.

According to Corbett[6], the possible radiation defects in the above temperature range include tetravacancy, vacancy-impurity pair (e.g., phosphor vacancy) and impurity gap. The annealing temperatures for tetravacancy, phosphor vacancy and iron gap are ~170, 150 and 160°C, respectively. However, it is not possible to positively identify the defect centers based on annealing behavior. More research is required to understand the nature of these new bands.

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CSO: 4008/1079

PHYSICAL SCIENCES

2 NEW AMORPHOUS SEMICONDUCTOR MULTILAYERED STRUCTURES

Beijing BANDAOTI XUEBAO [CHINESE JOURNAL OF SEMICONDUCTORS] in Chinese Vol 7, No 3, May 86 pp 331-333

[Article by Chen Zhiming [7115 3112 2494], Wang Jiannong [3769 1696 6593], Mei Xiangyang [2734 0686 7122], and Kong Guanglin [1313 0342 5259] of Institute of Semiconductors, Chinese Academy of Sciences: "Two New Types of Amorphous Semiconductor Multilayered Structures"; first paragraph is source supplied abstract]

[Text] Abstract: Two types of amorphous semiconductor multilayered structures not yet reported abroad were prepared by glow discharge. These are periodic multilayered structures using super thin a-Si:H/a-C:H and μc-Si:H/a-Si:H as the repeating elements, respectively. Cross-sectional TEM analysis of the samples showed sharp interfaces between layers, as well as the smoothness and homogeneity of all layers. The blue shift effect of the a-Si:H absorption edge in the a-Si:H/a-C:H structure observed in the absorption measurement is attributed to a quantum size effect.

As the study of the super lattice of crystalline semiconductors rapidly grows in depth and in breadth[1], amorphous semiconductor super lattice has attracted considerable attention because of the high tolerance in the match between the substrate and the material, as well as because the equipment and conditions required are less demanding. Since Ovshinsky[2] got the first patent on a practical amorphous multilayered semiconductor device in 1980 and Ogino[3] et al. published a report on studying the amorphous semiconductor multilayered structure $As_{40}Se_{60}/Ge_{25}Se_{75}$ in 1982, a great deal of progress has been made in amorphous semiconductors. In addition to sulfur group compounds, these repeat elements of periodic structures reported to date include a-Ge:H/a-Si:H, a-Si:H/a-SiN_x:H, a-Si:H/a-SiO_x:H, a-Si:H/a-SiC_x:H, as well as np and nipi types of doped a-Si:H modulated structures[4]. We are reporting two new periodic structures. The repeat element of one structure is a heterogeneous combination of a-Si:H/a-C:H. The other is an isomeric combination of μc-Si:H/a-Si:H. Both multilayered structures were prepared by radio-frequency glow discharge in a single reactor chamber by periodically varying the deposition atmosphere and power. The deposition device is essentially the same as that for the glow discharge of a-Si:H.

Because of the short sequence of orderliness of a-C:H, its absorption edge is very sensitively dependent upon conditions such as the deposition atmosphere and substrate temperature T_s. In order to obtain layered materials of wide band gaps, undiluted high purity (.9999) methane (CH_4) was used as the deposition source. When $T_s = 175°C$, the a-C:H film on quartz (absorption limit = 0.2 μm), approximately 1 μm thick, is transparent. Its index of refraction (in visible light region) was found to be about 1.8 by using the transmission spectrum of the thin film on quartz and the reflection spectrum of single crystal silicon substrate. The optical absorption edge is approximately 3.0 eV. To this end, the deposition temperature of every layer for the a-Si:H/a-C:H multilayered structure was fixed at 175°C. The source for depositing a-Si:H is H_2 with 10 percent high purity silane (.9999). The flow rate for depositing a-Si:H and a-C:H layers was 6 SCCM. The uncorrected pressures were 0.45 and 1.35 torr, respectively. In order to avoid cross-contamination between carbon and silicon, glow discharge was immediately turned off when a layer was deposited. The atmosphere was evacuated. After the pressure in the chamber is below 10^{-4} torr, the source gas for the next layer was used in large quantity to flush the chamber for 1 minute before we began to deposit the next layer. When depositing a-Si:H layers, the minimum rf power to sustain the glow was used. In depositing a-C:H, we chose a power approximately three times stronger. Under these conditions, the deposition rates for a-Si:H and a-C:H were ~ 60 and 40 Å/min, respectively.

Continuous plasma reaction was used to deposit multilayered film such as μc-Si:H/a-Si:H. The sources for μc-Si:H and a-Si:H are H_2 containing 2 and 10 percent high purity silane, respectively. The flow rates are 30 SCCM for both. A high pumping rate was used to maintain a low pressure atmosphere. The uncorrected pressure readings were ~ 0.07 and 0.1 torr, respectively. The power for depositing μc-Si:H is about twice that for a-Si:H. The deposition rates were ~ 15 and 10 Å/min, respectively. Because the previous gas composition is only left in the system for about 10 seconds after it is switched over (estimated by a sensitive gas pressure gauge), less than the deposition time for a monolayer, rf power is not turned off after the switch over. Instead, the power can be varied directly and it still results in a sharp interface between the two layers. Raman spectroscopy was used to study the microstructure of 0.5 μm thick single layers deposited under similar conditions. The a-Si:H specimen only showed a wide peak at 480 cm^{-1}. μc-Si:H clearly showed its two-phase characteristics. Its Raman spectrum consists of a wide peak at 480 cm^{-1} and a sharp peak at 519 cm^{-1} which represents crystalline silicon. Based on the ratio of the areas under the two peaks, we can estimate the ratio of the two constituents in the structure. It was experimentally found that the crystalline constituent may exceed 60 percent when T_s is higher than 250°C.

Figures 1(a) and (b) are the TEM photographs of the cross-sections of a-Si:H/a-C:H and μc-Si:H/a-Si:H specimens, respectively (see Plate I). An analysis shows that both specimens have sharp interfaces and the thickness of each layer is also uniform. Some layer thickness variations were caused by errors made in manual operation and had nothing to do with the thin film growth mechanism. The wavy looking top layers in Figure 1(a) were not caused by the growth process. Instead, it was due to the TEM sample preparation procedure. The sectional specimen is only a hundred angstrom or so thick after mechanical grinding and ion milling. It may "wrinkle" away from the substrate due to process induced stress or the intrinsic internal stress. This effect is not obvious in thin specimens and specimens with fewer layers.

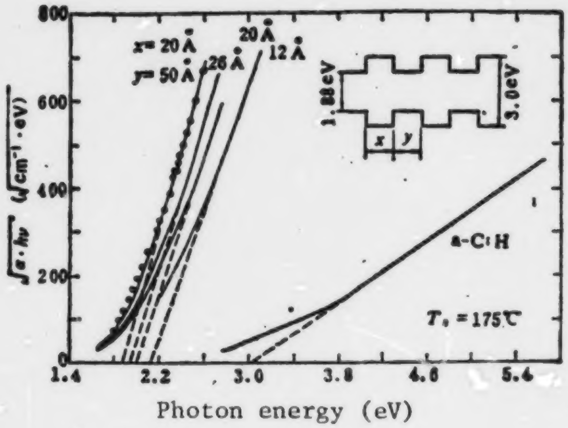

Figure 2. Taue Absorption Curves for Single Layer a-Si:H and a-C:H and Multilayered a-Si:H/a-C:H

—— a-Si:H/a-C:H · a-Si:H

Figure 2 shows the Taue curves reflecting the absorption edges of a-Si:H, a-C:H and multilayered a-Si:H/a-C:H films of different potential trap thicknesses. Because the absorption curves for a-Si:H and a-C:H fall in different spectral ranges, light absorption in the measurement of a-Si:H/a-C:H is mainly contributed by all a-Si:H layers. When the a-C:H potential barrier layer thickness is fixed at 20 Å and the a-Si:H layer is less than 50 Å thick, the curves show that the absorption edge of a-Si:H moves closer to that of the single layer a-Si:H (T_S = 175°C), from 1.88 eV to 2.1 eV (when it is 12 Å thick). It is believed that this blue shift of the absorption edge of the potential well is a typical quantum scale effect[5]. Based on the rough energy band model in Figure 2, as the potential trap layer thickness decreases, the wave function is under more constraints in a one-dimensional potential well, resulting in the localization of the lowest energy expansion states in the conduction band and valence band. Consequently, the edge of migration rate is moved toward higher energy to widen the band gap.

Other optical and electrical properties of these two new periodic materials are being investigated.

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APPLIED SCIENCES

INVESTIGATION OF LAW OF ATTITUDE CONTROL OF FLEXIBLE SPACECRAFT

Harbin HARBIN GONGYE DAXUE XUEBAO [JOURNAL OF HARBIN INSTITUTE OF TECHNOLOGY] in Chinese No 1, Mar 86 pp 50-57, 66

[Article by Wu Yaohua [0702 3852 5478] and Xu Shijie [1776 0013 2638]]

[Text] I. Introduction

The design of the control system of a flexible spacecraft is generally carried out using modern control theory (i.e., time domain techniques). It involves a large number of design parameters and requires large amount of computations; also, hardware implementation is very difficult. The main disadvantage of classical techniques is the difficulty in treating multivariable problems. In recent years, "modern frequency domain techniques" such as the inverse Nyquist lattice method, the characteristic trajectory method, and the multivariate root locus method have been developed. These techniques not only retain the advantages of classical methods, but are also capable of treating multivariate systems. This article discusses the problem of using classical methods to design the controller of a pitch channel where the pitch is uncoupled from the yaw and roll channels.

Section 2 of this article presents a mathematical model of the system; section 3 describes the stability analysis; section 4 discusses the problem of order reduction; section 5 addresses the problem of control parameter optimization; section 6 presents a numerical example; and, finally, section 7 gives a few conclusions of this investigation.

II. Mathematical Model of a Flexible Spacecraft

Figure 1 shows the schematic diagram of a flexible spacecraft. The spacecraft consists of a rigid main body and a pair of symmetrically placed solar panels. The moment of inertia of the main body is I_{2b}; the solar panel is composed of a membrane, a top plate, and a support rod. The mass of the top plate is m; the surface density of the membrane is σ; and the support rod is assumed to have uniform mass distribution. The pitch angle and twist angle are denoted by θ and α respectively; and $V(x,y)$ is the displacement in the Z direction. Under certain conditions, one can construct block diagrams expressed in terms of transfer functions, as shown in Figure 2 and Figure 3. Figure 2 corresponds to the case of unconstrained motion and Figure 3 corresponds to the case of constrained motion. The transfer functions obtained using either partial differential equations or the method of finite elements are identical. In the figures, ω_n, Ω_n are respectively the natural frequencies corresponding to unconstrained and constrained motions; k_n, K_n are respectively the modal gains. For a given set of system parameters and initial conditions, one can carry out the response calculations once ω_n, Ω_n, k_n, K_n are determined.

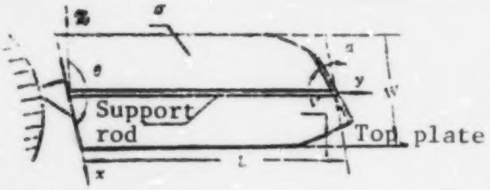

z
σ
θ
a
y
W
Support rod
Top plate
l
x

Figure 1. Schematic Diagram of the Spacecraft Structure

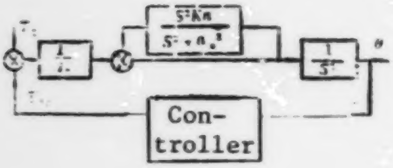

$\frac{S^2 K_n}{S^2 + \Omega_n^2}$
$\frac{1}{S^2}$
θ
Con-troller

Figure 2. Transfer Function Block Diagram for Unconstrained Motion

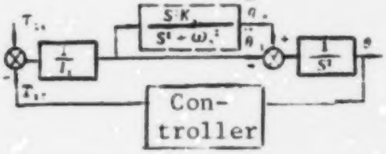

$\frac{S^2 K_n}{S^2 + \omega_n^2}$
$\frac{1}{I_z}$
$\frac{1}{S^2}$
+
-
θ
Con-troller

Figure 3. Transfer Function Block Diagram for Constrained Motion

III. Stability Analysis

The transfer function of the controller in Figure 2 and Figure 3 is $K_P + K_D S + K_I/S$. We shall now discuss the following two cases:

1. Neglecting the effect of flexibility

From Figure 2 one can derive the characteristic equation of the system as

$$I_z S^3 + K_D S^2 + K_P S + K_I = 0 \qquad (1)$$

Thus the stability conditions are:

$$K_D > 0, \quad K_I > 0, \quad K_P > \frac{K_I I_z}{K_D} \qquad (2)$$

2. Considering the effect of flexibility

From Figure 2, one can derive the open-loop transfer function of the system as

$$G(S) = \frac{1}{I_z S^2}\left[1 + \sum_{n=1}^{\infty} \frac{k_n S^2}{S^2 + 2\xi_n \omega_n S + \omega^2_n}\right]\left[K_P + K_D S + \frac{K_I}{S}\right] \tag{3}$$

In the above equation, a damping term has been added; the damping ratio ξ_n is determined experimentally.

From Figure 3, one can derive

$$G(S) = \frac{1}{I_z S^2}\left[1 - \sum_{n=1}^{\infty} \frac{S^2 K_n}{S^2 + 2Z_n \Omega_n S + \Omega^2_n}\right]^{-1}\left[K_P + K_D S + \frac{K_I}{S}\right] \tag{4}$$

By rewriting equations (3) and (4) in the following forms:

$$G(S) = \frac{1}{I_z S^2} \; \frac{\prod_{n=1}^{\infty} (S^2 + 2\xi_n \omega_n S + \omega^2_n) + \sum_{n=1}^{\infty} \dfrac{k_n S^2 \prod_{n=1}^{\infty} (S^2 + 2\xi_n \omega_n S + \omega^2_n)}{S^2 + 2\xi_n \Omega_n S + \omega^2_n}}{\prod_{n=1}^{\infty} (S^2 + 2\xi_n \omega_n S + \omega^2_n)} \cdot \left[K_P + K_D S + \frac{K_I}{S}\right] \tag{5}$$

$$G(S) = \frac{1}{I_z S^2} \; \frac{\left[K_P + K_D S + \dfrac{K_I}{S}\right] \prod_{n=1}^{\infty} (S^2 + 2Z_n \Omega_n S + \Omega^2_n)}{\prod_{n=1}^{\infty} (S^2 + 2z_n \Omega_n S + \Omega^2_n) - \sum_{n=1}^{\infty} K_n S^2 \dfrac{\prod_{n=1}^{\infty} (S^2 + 2Z_n \Omega_n S + \Omega^2_n)}{S^2 + 2Z_n \Omega_n S + \Omega^2_n}} \tag{6}$$

and comparing equations (5) and (6) using the equivalence property of transfer functions[5], one obtains:

$$G(S) = \frac{\left(1 + \sum_{n=1}^{\infty} k_n\right) \prod_{n=1}^{\infty} (S^2 + 2Z_n \Omega_n S + \Omega^2_n)}{I_z S^2 \prod_{n=1}^{\infty} (S^2 + 2\xi_n \omega_n S + \omega^2_n)} \left[K_P + K_D S + \frac{K_I}{S}\right] \tag{7}$$

Equation (7) shows that by considering the effect of flexibility, an infinite number of open-loop poles and zeros are added to the system. They are all conjugate pairs and are distributed in the left half of the S plane. The open-loop gain is increased by a factor of $1 + \sum_{n=1}^{\infty} k_n$. Therefore, if the system is unconditionally stable without considering the effect of flexibility, then it is stable when flexibility is considered; if the system is conditionally stable without considering flexibility, then since the gain is increased by a factor of $1 + \sum_{n=1}^{\infty} k_n$ when flexibility is considered, the system stability should be reexamined. This is called the unconditional stability theorem. Equation (7) shows that the above analysis is also applicable to other control laws.

IV. Order Reduction of a High Order Mathematical Model

It is seen from equation (7) that by considering the effect of flexibility, an infinite number of open-loop poles P_n and zeros Z_n' are added to the system:

$$\begin{aligned} P_n &= -\xi_n\omega_n \pm \omega_n\sqrt{1-\xi_n^2}\,j \\ Z'_n &= -Z_n\Omega_n \pm \Omega_n\sqrt{1-Z_n^2}\,j \\ n &= 1,2,\cdots,\cdots \end{aligned} \tag{8}$$

Since the root locus of a closed-loop system starts from the open-loop pole and ends at the open-loop zero, and the contribution of a pole to the system response varies inversely with the distance from the imaginary axis, we shall consider the following cut-off rule:

Let P_n, Z_n' denote the pole and zero of the nth order mode, then if they satisfy the condition

$$\begin{aligned} &\mathrm{Min}[R_e(P_n),R_e(Z'_n)] < \beta\cdot\mathrm{Min}[R_e(P_R),R_e(Z'_R)] \\ &n = 1,2,\cdots \end{aligned} \tag{9}$$

we shall neglect the nth order mode.

Here, $R_e(P_n)$, $R_e(Z_n')$ are the real parts of the pole and zero of the nth order mode;
$R_e(P_R)$, $R_e(Z_R')$ are the real parts of the pole and zero of the rigid main body,
β is the influence coefficient.

In other words, if the smallest real part of the pole or zero of the nth order mode is greater than β times the smallest real part of the rigid body pole or zero, then this particular mode should be neglected.

The choice of the influence coefficient will depend on practical experience and the required control accuracy. For the system described in this article, applying the above cut-off rule gives:

$$\mathrm{Min}[R_e(P_R),R_e(Z'_R)] = -\frac{K_r}{2K_D} \tag{10}$$

$$R_e(P_n) = -\xi_n\omega_n \tag{11}$$

$$R_e(Z'_n) = -Z_n\Omega_n \tag{12}$$

If we assume $\xi_1 = \xi_2 = \cdots = \xi_n = Z_1 = Z_2 = \cdots = Z_n = \xi$ and from Ref. 2:

$$\Omega_1 < \omega_1 < \Omega_2 < \omega_2 < \cdots < \Omega_n < \omega_n < \cdots \tag{13}$$

then the inequality becomes:

$$-\xi\Omega_n < -\frac{\beta K_P}{2K_D}$$

$$n = 1, 2, \cdots$$

i.e.,

$$\Omega_n > \frac{\beta}{2}\,\frac{K_P}{\xi K_D} \tag{14}$$

When this inequality holds, all higher order modes starting from the nth order will be neglected.

Equation (14) shows that the larger β is, the more terms are retained; thus the value of β is a measure of the degree of importance of the modes. When ξ increases, the number of terms retained decreases because with increased damping, the high-order oscillation attenuates more rapidly, hence a larger number of high order modes can be neglected.

Equation (14) also shows that the selection or deletion of a particular mode depends on the ratio between K_P and K_D, i.e., it depends on the distribution of poles of the rigid part of the system. This illustrates how the rigid main body interacts with the flexible appendages, and the relative contribution of each in the overall system response.

V. Optimization of the Controller Parameters

The previous section gives the range of controller parameters which lead to system stability. While the system would be stable for any parameter value within this range, the dynamic response and stability margin will be different for different parameter values. In this section, we shall use the Powell method to determine the optimum parameter value of the controller.

The Powell method is a conjugate search method with quadratic convergence property; it is particularly effective in solving ill-conditioned problems. The basic principle and the search procedure of the Powell method are discussed in Ref. 4.

To meet its mission requirement, a spacecraft must be able to function on-orbit for a long period of time with limited amount of fuel. Therefore, the fuel expenditure for attitude control must be minimized; however, in order to meet the requirements of communication, broadcast and scientific research, sufficient pointing accuracy must be maintained. These considerations suggest the selection of the following objective function:

$$J = \sum_{n=0}^{N} (\theta^2_n + u^2_n) \tag{15}$$

where θ_n is the discrete value of the pitch angle;
u_n is the control at the nth step;
N is the number of computation steps.

This objective function consists of the sum of squares of the expenditure of control energy and the attitude error, so that the mission requirement is satisfied based on a compromise between control accuracy and control expenditure. Since the system is linear, the optimal solution can be obtained for an arbitrary initial value of the controller parameter. To compute the objective function, we must first perform calculations of the system response. For the system shown in Figure 2, we can write the following state equation (including the damping term):

$$\dot{X}_1 = AX_1 + Bu \tag{16}$$

where

$$X_1 = \begin{bmatrix} \theta_1 \\ \dot{\theta}_1 \\ q_1 \\ \dot{q}_1 \\ \vdots \\ q_n \\ \dot{q}_n \end{bmatrix}; \quad A = \begin{bmatrix} 0 & 1 & & & & & \\ 0 & 0 & & & & \text{\Large 0} & \\ & & 0 & 1 & & & \\ & & -\omega^2_1 & -2\xi\omega_1 & & & \\ & & & & \ddots & & \\ & \text{\Large 0} & & & & 0 & 1 \\ & & & & & -\omega^2_n & -2\xi\omega_n \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 1 \\ 0 \\ K_1 \\ \vdots \\ 0 \\ K_n \end{bmatrix}$$

The input equation is

$$u = (T_{2e} + T_{2c})/I_2 \tag{17}$$

the output equation is

$$\theta = \theta_1 + \sum_{n=1}^{\infty} q_n \tag{18}$$

and the control equation is

$$T_{2c} = K_P\theta + K_D\dot{\theta} + K_I \int_0^t \theta dt \tag{19}$$

where T_{2e}, T_{2c} are respectively the disturbance torque and the control torque; I_2 is the moment of inertia of the rigid spacecraft; other notations are defined in Figure 2. Based on equations (16)-(19), response calculations can be carried out for a given set of initial conditions. The stopping rule used in this paper is when the differences between all the components of two consecutive solutions of the optimization procedure are less than or equal to some specified accuracy measure ε, i.e.,

$$\max\|X_{n+1} - X_n\| \leq \varepsilon \tag{20}$$

Figure 4 shows a flow diagram of the Powell method. e_k denotes a unit coordinate vector, ε is the accuracy measure, A, B are respectively the coefficient matrices given in equation (16), and A_1, B_1 are state transition matrices. For a given initial coordinate direction P and initial point X_o, an optimum point $X^{(1)}$ is determined along each of the directions $P_1, P_2, \cdots, P_N$. The subscript along each direction is advanced by one, and the P_1 direction is discarded; the direction $X^{(1)}-X_o$ is substituted into P_N, and an optimum solution $X^{(2)}$ is obtained along the direction P_N. If $\|X^{(2)}-X_0\| \leq \varepsilon$, then $X^{(2)}$ is accepted as the optimum solution; otherwise the above procedure is repeated.

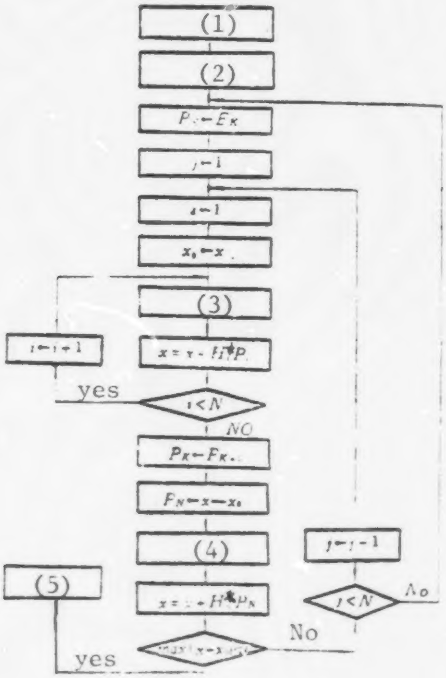

(1)
(2)
$P_i \leftarrow E_K$
$j \leftarrow 1$
$i \leftarrow 1$
$x_0 \leftarrow x$
(3)
$i \leftarrow i+1$
$x = x + H_i^* P_i$
yes
$i < N$
NO
$P_K \leftarrow P_{K+1}$
$P_N \leftarrow x - x_0$
(4)
$j \leftarrow j+1$
(5)
$x = x + H_N^* P_N$
$j < N$
No
No
yes

Figure 4

Key:

1. Input A, B, ε, e_k, X_o
2. Determine A_1, B_1
3. Determine optimum step size
4. Determine H_N^*
5. Print x, J(x)

VI. Numerical Example

Table 1 presents the structural parameters of the spacecraft shown in Figure 1. Based on these parameter values, the characteristic values and modal gains of the system can be determined using the method of Ref. 2, as shown in Table 2 and Table 3 (only the first 5 modes are tabulated). Now we can proceed to carry out the response calculations.

Table 1. Structural Parameters

L (m)	W (m)	σ	P (kg)	I_{2b} (Newton·m·sec^2)
4.8	2.4	0.396	5	1360
z	Z	m^*		I_z (Newton·m·sec^2)
0.01	0.01	0.153		1365

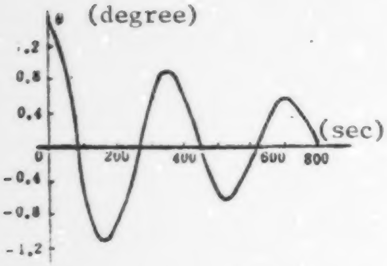
Table 2. Characteristic Values and Modal Gains of Unconstrained Motion

n	ω_n	n	k_n
1	.233270E+01	1	.262593E−02
2	.698801E+01	2	.299867E−03
3	.116462E+02	3	.107275E−03
4	.163065E+02	4	.535665E−04
5	.209670E+02	5	.327736E−04

Table 3. Characteristic Values and Modal Gains of Constrained Motion

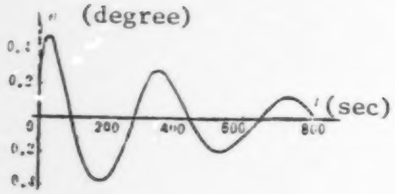
n	Ω_n	K_n
1	.232969E+01	.260689E−02
2	.698801E+01	.289762E−03
3	.116462E+02	.104336E−03
4	.163050E+02	.532414E−04
5	.209655E+02	.322101E−04

By substituting the optimized controller parameters into the system, we can generate response curves corresponding to different initial conditions and external torques, as shown in Figures 5, 6, 7. Figure 5 shows the response curve for the case where no external torque is present, and the initial pitch angle is 1.5°, the initial pitch rate is zero, and the initial values of all modes are zero; Figure 6 shows the response curve for the case where the system is acted on by the solar radiation torque, and all initial conditions are zero; Figure 7 shows the response curve for the case where solar radiation torque is present, the initial pitch is zero, and the initial pitch rate is 0.1 deg/sec. In Figures 5, 6, 7, system responses have been calculated for several different conditions, but they only differ in the 4th decimal place, hence these curves cannot be separated.



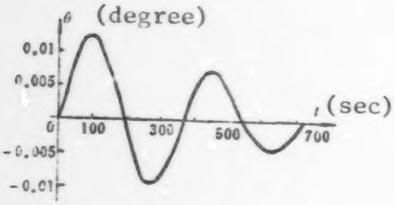
1. Rigid
2. Flexible, retaining 1st constrained mode
3. Flexible, retaining 1st unconstrained mode
4. Flexible, retaining first 20 unconstrained modes

Figure 5. System Response When the Initial Pitch Is 1.5°



1. Rigid
2. Flexible, retaining 1st contrained mode
3. Flexible, retaining 1st unconstrained mode

Figure 6. System Response Under Solar Radiation Torque



1. Rigid
2. Flexible, retaining 1st constrained mode
3. Flexible, retaining 1st unconstrained mode

Figure 7. System Response When Collision With Micro Meteors and Solar Radiation Pressure Are Considered

VII. Conclusion

On the basis of the above analysis and calculations, one can draw the following conclusions:

1. For a flexible spacecraft where the pitch channel is decoupled from the yaw and roll channels, a PID controller can be used for the pitch channel.

2. The stopping rule described in this article is very simple and easy to apply; the selection or deletion of a mode depends on the structural damping and the pole distribution of the rigid part of the spacecraft.

3. Substituting the optimized parameters obtained from a rigid spacecraft into a flexible spacecraft produces essentially the same responses. This illustrates that for the system described in this article, the optimized parameters can be used for designing the control system of a flexible

spacecraft under either constrained motion or unconstrained motion; the resulting control performance has proved to be satisfactory.

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APPLIED SCIENCES

PRODUCTION OF NONCAKING POTASSIUM NITRATE FOR USE IN KINESCOPES

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[Article by Xu Ji [7312 6549], Yin Yunxing [3009 0061 5281], Zhang Wenjun [1728 2429 0193], and Ye Ting [0673 2185] of the Shanghai Changjiang River Chemical Works]

[Test] Potassium nitrate is a raw material used in the chemical industry in large plants, mainly in the glass industry, the heat treating of metals, fireworks, gunpowder, medicine, reagents, etc. China's annual usage is more than 10,000 tons. Although product quality meets national standards, this produt and other salts are similar in that they very easily cake. Generally in a number of hours they begin to agglomerate, and after a number of days they become a solid material. This is not only difficult for the consumer to manipulate, but more importantly: (1) it is an oxidizing agent; when broken up, it is easy to cause detonation by striking it, so it is very difficult to handle; (2) solid potassium nitrate, even if already powdered, is not easy to mix, and this decreases the product quality; (3) automatic material feeding equipment cannot be used, so it can not be adapted to modern production requirements. Due to this, solution to the caking problem of potassium nitrate, improving its physical properties, has become an urgent production task.

Special purpose potassium nitrate of a particular specification was imported from the United States in 1982 for the Shanghai Kinescope Glassworks for a trial assembly line manufacture of 4 million glass kinescope casings. The quality of this potassium nitrate had to meet top national standards and also satisfy strict size requirements. Moreover, the caking phenomenon was not allowed.

During the last 2 years, we investigated and experimented with more than 80 batch lots on a test production basis. We found a feasible technological method and a surface activity preparation the product quality and size of which basically conformed to the requirements. After standing for a long time, there was no caking. Also, it passed physical and chemical testing and curing experiments by the Corning Glass Company of the United States proving that it conforms to requirements (six Shanghai electron tube factories and glassworks among others have also conducted experiments, and it meets requirements). Especially, passing the requirements of the Shanghai Kinescope Glassworks using the U.S. import in the large batch production assembly line for glass kinescope casings proves that this non-caking potassium nitrate conforms to production requirements. Having passed the technology appraisal of the first quarter of 1984, we officially went into operation. Here now is a simple introduction covering five aspects of the product.

I. Choice of Technical Method

According to the present understanding, the following two items are important in the technological method within and outside China:

1. The double decomposition of salt method:

$$KCl + NaNO_3 \rightarrow KNO_3 + NaCl$$

This method is technologically simple but the cost is very high and there is little use for the side product, NaCl.

$$KCl + NH_4NO_3 \rightarrow KNO_3 + NH_4Cl$$

The cost of this method is very low and the side product, NH_4Cl, is a nitrogenous fertilizer, but the equipment readily corrodes.

2. The Acidolysis Method

$$KCl + HNO_3 \rightarrow KNO_3 + NaCl$$

$$3HCl + HNO_3 \rightarrow NOCl + Cl_2 + 2H_2O$$

$$2NOCl + 4HNO_3 \rightarrow 6NO_2 + Cl_2 + 2H_2O$$

$$4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$$

The strong points of this method are that it does not require alkali, the efficiency is high, the cost is low, and the side product is Cl_2, but the equipment readily corrodes, material quality requirements are high, and there are waste gases to be disposed of.

Production in China has mainly adopted the first of these technological methods, but because product quality requirements are not the same, and there are differences among specific handling conditions, production outside China since the 1970's began adopting the second of these production methods.

II. Inquiry Into the Caking Mechanism

According to crystal bridging theory, it is thought that in powders and granular materials, when fusion, dissolution, consolidation, and other reactions take place at the particle contact points, they can solidify. The degree of consolidation is determined by the inherent properties of the material (temperature of crystallization, hygroscopicity, fusibility, granularity, crystal structure and composition, etc.) and changes due to variation of external conditions (humidity, temperature, pressure, time, etc.), mainly through absorption of moisture → particle surface fusion → evaporation of moisture and separating out of crystals → binding by bridges between particles and ensuing consolidation. Also, as time goes on, binding takes place among these crystals, gradually forming large cakes.

According to capillary absorption theory, the existence of capillary absorption forces within a powder gives rise to capillary adhesion and causes powder agglomeration. The capillary absorption forces can be expressed in the following equation:

$$\rho = \frac{2r\cos\theta}{R}$$

where ρ is the capillary absorption force, r is the liquid surface tension, R is the radius of curvature, and θ is the angle of contact within the powder.

Due to the effect of the capillary absorption force, the water content of the powder is more easily held on the surface, increasing the saturated water vapor pressure of crevice bound water within the powder, causing the fine powder or the water absorbed on the powder surface to become saturated, or supersaturated, causing more crystallization within water droplets, and resulting in adhesion and cake formation.

The above two theories are interrelated, and both can explain the origin of caking.

III. Screening of Anti-caking Surface Active Preparations

According to the aforementioned theory, there are three methods dealing with the prevention of caking:

1. Method of preventing contact between particles: this method has definite effects mainly in non-water soluble powders such as kaolin additives, diatomaceous earth, activated alumina, metal salts of fatty acids, etc.

2. Method of preventing hygroscopicity by forming a waterproof film on the particle surface: film forming agents, paraffin wax utilization, all types of resins, certain types of active agents, etc.

3. As surface mositure evaporates, use crystallization and denaturing agents to separate out material which is not readily formed into solid crystals: all types of active agents, high polymeric active agents and compounds, acidic dyes, etc, have these effects. But the selection among these types of chemical products and anti-solidifying agents is critical.

Presently, both within and outside China, three main types of fundamental anti-caking additives have been adopted:

(1) surface active agents

(2) organic silicons

(3) other high polymer substances

Due to the addition of surface active agents, the dissolving area of intercrystalline liquid bridges is reduced and the surface tension is lowered in a supersaturated solution of the crystals, changing the form of the crystals as they are separated out, and also absorbing an enclosing film onto the surface of the crystals. In this way, contact with moist air is avoided, thereby preventing caking. For this reason, surface active agents are now mainly used.

Based on the properties and many uses of potassium nitrate, of special importance is glass for kinescopes and requirements for other uses of glass. Along with very good anti-solidifying potassium nitrate preparations, it must also satisfy the following six conditions:

(1) it must have long lasting anti-caking effectiveness

(2) it must have good chemical stability

(3) it cannot affect the internal mass

(4) it must have no bad effect on the use of the KNO_3 product

(5) it must be convenient to use and have basically no effect on the original production technology

(6) it must be low cost and easy to prepare

In this regard, testing and comparison must be performed for each type of surface active agent. Select each surface active agent and perform a small scale test by taking a 500g sample and, after treatment, place it in a plastic bag, seal, and keep in a cool, dark place. Increase the pressure by 5kg, and examine the caking situation. The anti-caking properties of several representative samples are listed in the table below.

The Anti-caking Properties of Several Surface Active Preparations

experiment serial No.	type of active agent	amount of additive	caking situation (days) 1	5	10	30	60	90	120	150	180
1	blank	-	B	C	D	D	D	D	D	D	D
2	strongly water absorbing	5/10,000	A	B	C	D	D	-	-	-	-
3	Y_{80}	5/10,000	A	A	A	A	A	A	A	A	A
4	cationic surface active	5/10,000	A	B	C	D	D	-	-	-	-
5	non-ionic surface active	5/10,000	A	C	D	D	D	-	-	-	-

The extent of caking is symbolized as follows:

A indicates the optimum powdered state

B indicates the initial stages of caking

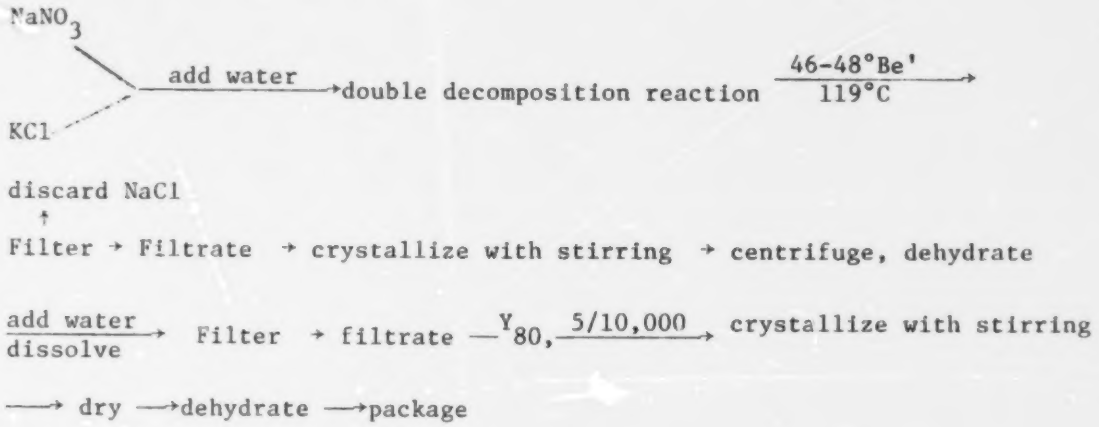
C indicates the partially caked condition

D indicates the totally caked condition

From the table, it can be seen that Y_{80} is the most ideal anionic surface active agent for prevention of caking in potassium nitrate.

IV. Production Method

1. Production process


$NaNO_3$
KCl
add water
double decomposition reaction
46-48°Be'
119°C
discard NaCl
Filter
Filtrate
crystallize with stirring
centrifuge, dehydrate
add water
dissolve
Filter
filtrate
Y_{80}, 5/10,000
crystallize with stirring
dry
dehydrate
package

2. Laboratory formulation

Weigh out 500g of $NaNO_3$ and place in a 21 beaker fitted with a stirrer: add water water and heat to dissolve. Add 432.5g of Kcl ($NaNO_3$:KCl = 100:86.5). After heating until all is dissolved, evaporate and concentrate to 199°C, 46-48°Be'. Filter with heating (filter and discard NaCl). Cool the filtrate with stirring. After the crystals separate out, dry, the yield of potassium nitrate is 400g. Place this in a 1 liter beaker, add 240ml of distilled water (KNO_3:H_2O = 100:60), add heat to dissolve and filter with heating. Place the filtrate in a slowly stirred 800ml beaker and, when the temperature is 70-80°C, add Y_{80} to 5kg/10,000 kg. After crystallization is complete, dry dehydrate. This is the product.

3. Industrial production method

In a stirred and coil heated $4m^3$ double decomposition reaction oven, place 1.5 tons of mother liquor (38°Be', 20 percent content), add 500kg of $NaNO_3$. Heat and, after dissolving add 450kg KCl to obtain a saturated solution. Evaporate and concentrate to 119°C, 46-48°Be'. Filter while hot, discard the filtered NaCl, and place the filtrate in a stirred and cooled crystallization chamber. Stir for one full day, separate out the crystals, and dry.

Place the yield of 500kg of KNO_3 in a stirred and coil heated evaporation oven. Add 300kg of distilled water ($KNO_3:H_2O = 100:60$) and heat to dissolve. Filter while hot and place the filtrate in a crystallization oven. When the temperature is 70-80°C, add 5kg/10,000 kg of Y_{80} activator. With slow stirring and slow cooling, separate out the standardized crystals and dehydrate to obtain the product.

V. Conclusion

1. Y_{80} anionic surface active agent not only can be regarded as an excellent anti-caking additive for potassium nitrate for use in black and white kinescopes, but also for electron tubes and other glass industry products that use anti-caking preparations of potassium nitrate.

2. Y_{80} anionic surface active agent is easy to prepare, convenient to use, and can prevent caking of potassium nitrate at a concentration of only 5kg/10,000kg. In actual tests, when stored for up to half a year, there was no caking.

3. Y_{80} anionic surface active agent treated potassium nitrate not only does not affect the mass of the potassium nitrate, but also raises the quality of the kinescope and other glass product technology.

4. By our test product, we discovered a feasible production technology method. We also mastered each technical condition and were able to adapt to each consumer requirement.

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APPLIED SCIENCES

USE OF ELASTIC COMPOSITE MATERIAL IN NITROGEN FERTILIZER

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[Text] Cavitation is a phenomenon that occurs frequently in hydraulic turbines, naval ship propellers, water pumps, and other high speed rotating hydraulic machinery. Cavitation not only reduces the efficiency and longevity of hydraulic machinery, but also causes such equipment to sustain serious damage and poses a direct threat to safe production. In cities which have used XCA composite material in their tap water pumps, not only has their unit electrical usage dropped 2.62-8.1 percent, and the net increase in water pumping quantity has been 57-120 tons/hr[1,2], but also the longevity of the water pumps was clearly extended. For example, previously after 400-500 hours, the impeller blades developed holes and required immediate replacement, but impeller blades to which a coating of XCA composite material was applied had small holes only at the base of the blades after 1,462 hours. After 1,002-1,376 hours, the coating was mostly intact.

Severe cavitation damage occurred in China's imported circulating water pumps in 10 to 20 300,000 ton synthetic ammonia plants. In some pumps, cavitation had clearly occurred after 2 to 3 months of operation. Pumps with slight cavitation could only run for 8 to 9 months. In the best case, they could only run through one inspection period (about 7,200 hours) before requiring an overall and impeller blade replacement. The Nanjing Qixiashan Chemical Fertilizer Plant has imported four model EPB62 circulating water pumps for their 300,000 ton synthetic ammonia plant. For a long time, there has been severe cavitation requiring overhaul and impeller blade replacement after running for one inspection period (about 7,200 hours). At times, other parts needed replacement as well. Between 1979 and 1981, trying rubber and epoxy glass to protect the blades, the results were not good. Opening the casing for inspection after about 10 months of operation, it was discovered that the coating had peeled off. The base metal was perforated by cavitation. At the time of the 1984 overhaul, they used XCA composite material to protect their impeller blades, obtaining quite satisfactory results.

Experimental Section

I. The main technological parameters of the circulating water pumps:

Model: EPB62	Position No. G9401 A-D
Impeller blade material: QT 45-5	Rated revolutions: 985 r/min
Lift: 40m	Rated flow: 9,000 m^3/h

Drive: Turbine powered 1,155kW (G9401A,B,C)

Auxiliary electric powered 1,400kW (G9401D)

Manufacturer: French Latuo[phonetic]

II. Raw and Processed Materials

Components of XCA composite material: XCA-201, XCA-209, XCA-40, XCA-20, solid fillers (the above products were from the Chongqing Hongqi Adhesive Works), vinyl acetate (analytical purity), acetone (industrial grade).

III. Work Techniques

Work measures and techniques are explained below:

1. The quality of the grit blasting has a direct effect on the base metal and the bonding strength of the coating; it must be handled carefully.

2. Using 100g of surface treatment preparation, an area of approximately $1m^2$ can be treated; using a fine hair brush (paint brush), apply one even surface coat.

3. Always use a fine hair brush for application. Mix according to the chart of components, following the sequence from top to bottom, each time adding one ingredient, and it must be well mixed before adding the next one.

Two coats are applied to the bottom layer, the material in each coat consisting of 25g of XCA-201. This is suitable for application to a $1m^2$ area. The composition of the bottom layer should not contain more than 50g of XCA-201. One coat is applied to the middle layer, the material of which consists of 40g of XCA-201. This is suitable for application to a $1m^2$ area. The number of coats in the surface layer is determined by the thickness requirements. Using a material consisting of 40g of XCA-201 is suitable for application to an area of $1m^2$. Using a material consisting of 1,000g of XCA-201 and applying to an area of $1m^2$ will give a thickness of 1mm.

4. "Lay up" phase is set by the volatility of the liquid so as to prevent bubbling during baking.

grit blast to remove rust

→

acetone rinse 2-3 times

→

surface treatment	
composition	proportion
20*	10
acetone	190

*XCA component XCA-20, similarly below

COATING			
COMPOSITION	PROPORTION		
	BOTTOM LAYER	MIDDLE LAYER	SURFACE LAYER
201	100	100	100
209	120	38	–
filler	150*	–	–
20	54	–	–
40	160	78	40
vinyl acetate	approx. 160	approx. 100	approx. 60

*80 for application of 2nd coat

→

LAY UP (h)
20–30

→

BAKING (h)
progressive temperature increases 60°C(2) 80°C(2) 100°C(2) 120°C(4)

5. After baking, let it naturally cool down to room temperature to reduce the internal stress of the coating. The cooling radient affects the quality of bonding due to the dissimilar coefficients of contraction of the base metal and the coating.

Results and Discussion

Impeller blades treated with XCA type composite material ran from 10 December 1984 to 31 August 1985, a total of 6,240 hours. When opened for inspection, it was found that the applied layer was mostly intact. On a few blades, on the side of water entry where the most severe cavitation occurs, there were small areas where the coating had peeled off, revealing the base metal on which traces of cavitation could be seen. Some had grey metal surfaces but did not show evidence of cavitation.

The following factors relate to the cavitation resistance of a coating of XCA type composite material:

1. A surface layer of XCA composite material has good cavitation resistant properties.

The resistance to cavitation of each material in a rotating disk cavitation generator is shown in Table 1.

It can be seen from the experimental results, if the relatively cavitation resistant 1Cr 18Ni 9Ti in an unrusted condition is given a relative cavitation resistance index (volumetric loss rate of 1Cr 18Ni 9Ti/volumetric loss rate of another material) of 1, then, by comparison, the cavitation resistance of XCA composite material is 7.3 times higher than that of 1Cr 18Ni 9Ti, 43 times higher than that of A_3 steel, and 2,430 times higher than that of epoxy carborundum.

Regarding the mechanism of cavitation, though not the only explanation, no one doubts that the break up of bubbles occurs at a certain fluid flow pressure.

Table 1: The cavitation resistance of each material

Material	Volumetric Loss Rate (mm^3/h)	Cavitation Resistance Index (E_v)
epoxy carborundum	183.1	0.003
teflon	23.4	0.021
A_3 steel	2.9	0.17
#35 steel	1.8	0.27
PPG coating	0.9	0.56
1Cr18Ni9Ti	0.5	1.00
1Cr13	0.21	2.33
stellite	0.073	6.71
XCA type material	0.067	7.31

Elastic materials all have good resistance to cavitation. This is because the fluid flow pressure at which bubbles rupture is absorbed by the rotating bonds of the flexible molecular chains within the body of the elastic material. Also, the deformation of large molecular chains can transmit and disperse the absorbing power, rapidly attenuating the impulsive force, thus strongly reducing the cavitation damage produced by bubble rupturing. When studying the impact at the liquid/solid interface, one should consider the elasticity of the material and use the hydraulic impact equation[3]:

$$\frac{1}{2}\rho v^2 = \frac{1}{2}\frac{P^2}{E'} + \frac{1}{2}\frac{P^2}{E''}$$

where: ρ is the liquid density
v is the liquid impact velocity
P is the liquid impact pressure
E' is the liquid elastic modulus
E'' is the solid elastic modulus

By calculation, it can be discovered that the instantaneous impact strength has 1/14th the effect on an elastomer as it does on a steel surface.

2. XCA composite material has excellent mechanical and wear resistance properties.

From Table 2, it can be seen that XCA composite material has excellent overall mechanical properties. The wear resistance of polyurethane rubber (with a surface layer of XCA material) is outstanding; under conditions of severe wear and tear, the wear resistance of polyurethane rubber is more than 10 times greater than that of other rubbers[4]. The errosion and wear of polyurethane elastics is 7.5 times lower than the highly wear resistant engineering plastic nylon[5].

Table 2: Surface layer mechanical properties of XCA material

Tensile strength (kg/cm²)	300-400
100% modulus (kg/cm²)	50-70
Fracture elongation (%)	400-500
Hardness (A)	80-90
Permanent deformation (%)	10-15

3. XCA composite material has excellent water resistance.

From Table 3, it can be seen that the shearing and bonding strength of XCA was lowered by only 4.3 percent after immersion for 2 months, while other materials had obvious losses after only 1 month of immersion. Thus, XCA has excellent water resistant and bonding properties.

Table 3: Water resistant bonding (unrusted steel-unrested steel) strength (kg/cm^2) of each material

material experimental conditions	XCA composite material	unmodified epoxy	polysulfide rubber modified epoxy	polaymide modified epoxy
pre-soaking shear strength	234	118	315	≥ 250
shear strength after immersion in cold water for 1 month	224*	77	118	224
percent decrease	4.3	35	62.5	10.4

*data is from 2 months immersion in cold water

Conclusion

1. After 6,240 hours, on impeller blades treated with XCA, only small areas of the coating peeled off and, in fact, few of the peeled areas showed a grey metal surface; it was estimated that they could have gone another inspection period. In this way, whereas formerly they could go 1 year with one overhaul, they could extend this to 2 years running with one overhaul. Consequently, in October 1985, the impeller blades of 3 frequently used circulating water pumps were entirely coated with XCA composite material.

2. Production running and inspection results indicate that there has not been the problem of piping blockages from peeled off coating material.

3. The Qixiashan Chemical Fertilizer Plant daily production value is greater than 600,000 yuan. If on a 500,000 yuan plan, then following an inspection and repair period of about 10 days, the production is increased by 5 million yuan. This does not include energy, materials savings, replacements, manpower, and other economic effects of production.

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APPLIED SCIENCES

ENERGY MODEL OF FREE-ELECTRON LASER

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 13, No 7, 20 Jul 86 pp 385-391

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[Text] Abstract: In this paper, an energy model of FEL was set up to calculate the energy transfer rate of FEL under the conditions of small signal and strong signal respectively. This model was simply in calculation, clear in physical meaning and adequate for FEL with different magnetic structures, such as FEL with wigglers, FEL with axial magnetic field, and FEL with helical axial magnetic field combination. It could be used to deal with various problems such as harmonic radiation, short wavelength radiation, parameter variations and so on. The model is suitable for three dimensional problems.

I. Introduction

Ever since the debut of the free electron laser in 1976, a number of theories have been developed, including the virtual photon theory[1], the coupled Maxwell-Boltzmann equation[2], the single particle model[3], and the quantum theory[4]. Although these theories have been successfully applied, the calculations are tedious and a number of approximations are made. The shortcomings became obvious for strong signal conditions and when the one-dimensional model no longer applied, like the case when an axial magnetic field is introduced into the helical magnetic field to collimate the electron beam. It should also be pointed out that these theories each apply to a specific situation and lack generality. In order to overcome these inadequacies, we propose a new model to simplify the calculation. The model is widely applicable and also gives a clearer physical picture. As is well known, when relativistic electrons of a certain velocity or energy enter the laser, their interaction with the electromagnetic field and certain phase matching conditions cause their state of motion to change. This leads to an exchange of energy between the radiation field and the electron beam. Such energy exchange in turn causes further changes in the electron motion and more energy exchange. This interaction between the field and the electron beam continues until the phase matching condition is no longer satisfied. In this interaction process one can on the one hand regard the energy changes of the relativistic electrons and the radiation field as functions of the electron state of motion parameters and obtain the energy conversion efficiency and the radiation intensity change by determining the electron state parameters as was done in the above theories; one can also regard the state of motion of the relativisitic electrons as a function of their energy and represent the interaction process and results of the electron and the field in terms of energy changes. These two different mathematical treatments actually reflect exactly the same physics. In view of this, and considering the fact that the law of energy conservation must be obeyed in the interation of the relativistic electrons and the electromagnetic field, we establish the energy model of the free electron laser described here. The characteristics of the model may be put succintly as follows. The changes of the motion parameters of the relativistic electrons are expressed as changes in the corresponding energy parameters; in the meantime, a functional relationship is established between changes in the radiation intensity and changes in the electron energy via the law of energy conservation. As we will see below, the calculation process is greatly simplified by replacing the coupled electromagnetic equations with a single energy conversion equation. It should especially be pointed out that the model is applicable to free electron lasers with different magnetic field structures such as FEL with wigglers, FEL with axial magnetic field, and FEL with axial and helical magnetic fields. The model may not only be used in the calculation of the energy conversion efficiency and gain of a FEL, but is also useful in interpreting harmonic radiation, short wavelength radiation, and parameter variation problems.

II. Basic Equations

In this section we derive the equation of energy conversion of a free electron laser with a circularly polarized wiggler from the Lorentz equation and the energy equation of a single relativistic electron. The overall macroscopic effects of the relativistic electron beam can then be obtained from the average of the single electron effects.

We represent B_w of the circularly polarized Wiggler, and E_r and B_r of the radiation field respectively as

$$\boldsymbol{B}_w - B_w\{\hat{e}_x\cos\xi_w + \hat{e}_y\sin\xi_w\} \qquad (1)$$

$$\begin{aligned} \boldsymbol{E}_r &- E_r\{\hat{e}_x\cos\xi_r - \hat{e}_y\sin\xi_r\} \\ \boldsymbol{B}_r &- E_r/c\{\hat{e}_x\sin\xi_r + \hat{e}_y\cos\xi_r\} \end{aligned} \qquad (2)$$

where B_w is the amplitude of the helical magnetic field, $\xi_w = K_w z + \phi_w$, $K_w - 2\pi/\lambda_w$, λ_w is the spatial wavelength of the helical field, is the initial phase of the relativistic electron upon entering the helical field, $\xi_r = K_r z - \omega_r t + \phi_r, \omega_r - cK_r$ is the angular frequency of the radiation field, ϕ_r is the corresponding initial phase, and E_r and E_r/c are respectively the amplitudes of the radiation field vector and the magnetic field vector, represented as functions of the z coordinate.

The energy equation and the dynamic equation of motion of the single relativistic electron are respectively

$$\frac{d}{dt}\gamma = -\frac{|e|}{mc^2}\boldsymbol{v}\cdot\boldsymbol{E}_r \tag{3}$$

$$\frac{d}{dt}\gamma\boldsymbol{v} = -\frac{|e|}{m}\{\boldsymbol{E}_r + \boldsymbol{v}\times(\boldsymbol{B}_r + \boldsymbol{B}_w)\} \tag{4}$$

where γ is the relativistic energy parameter and |e| and m are respectively the charge and the rest mass of the electron. Equation (4) is a vector equation and its x and y components are

$$\begin{aligned}\frac{d}{dt}\gamma\dot{x} = {} & \frac{|e|B_w}{m}\dot{z}\sin\xi_w \\ & -\frac{|e|E_r}{m}(1-\beta_z)\cos\xi_r\end{aligned} \tag{5}$$

$$\begin{aligned}\frac{d}{dt}\gamma\dot{y} = {} & -\frac{|e|B_w}{m}\dot{z}\cos\xi_w \\ & +\frac{|e|E_r}{m}(1-\beta_z)\sin\xi_r\end{aligned} \tag{6}$$

with $\beta_z = \dot{z}/c_0$.

Integrating both sides of Eq.(5), we have

$$\begin{aligned}\gamma\dot{x} = {} & \frac{|e|E_r}{m\omega_r}\sin\xi_r - \frac{|e|B_w}{mK_w}\cos\xi_w \\ & -\frac{|e|}{m\omega_r}\int\sin\xi_r\,dE_r\end{aligned} \tag{7}$$

where the constant of integration has been dropped. The purpose of this formulation is to simplify the equation without affecting the calculation results. Similarly we have

$$\begin{aligned}\gamma\dot{y} = {} & \frac{|e|E_r}{m\omega_r}\cos\xi_r - \frac{|e|B_w}{mK_w}\sin\xi_w \\ & -\frac{|e|}{m\omega_r}\int\cos\xi_r\,dE_r\end{aligned} \tag{8}$$

Substituting (7) and (8) into (3), we have

$$\begin{aligned}\gamma\frac{d}{dt}\gamma = {} & -\frac{|e|E_r}{mc^2}\{\gamma\dot{x}\cos\xi_r - \gamma\dot{y}\sin\xi_r\} \\ & -\left(\frac{|e|}{mc}\right)^2\frac{E_rB_w}{K_w}\cos(\xi_w+\xi_r) \\ & +\left(\frac{|e|}{mc}\right)^2\frac{E_r}{\omega_r}\Big\{\cos\xi_r\int\sin\xi_r\,dE_r \\ & -\sin\xi_r\int\cos\xi_r\,dE_r\Big\}\end{aligned} \tag{9}$$

Equation (9) no longer contains any transverse motion parameters explicitly. To eliminate the longitudinal motion parameters, we let

$$\begin{aligned} \beta_z &= \beta_{z0} - \delta\beta_z \\ \gamma &= \gamma_0 - \delta\gamma \end{aligned} \tag{10}$$

where the subscript "o" indicates the initial value. Since $\beta_\perp \ll \beta_z \approx 1$, the following approximate relationship follows from the definition of γ:

$$\delta\beta_z \approx \frac{1}{\gamma_0^2}\left(\frac{\delta\gamma}{\gamma_0}\right) \tag{11}$$

It can be shown that this approximation does not affect the calculation results.[5]

Equation (11) shows the functional dependence between the longitudinal velocity of the relativistic electron and its energy. Hence,

$$\begin{aligned} \frac{dz}{dt} &= c\beta_z = u - \frac{c}{\gamma_0^2}\left(\frac{\delta\gamma}{\gamma_0}\right) \\ z &= z_0 + ut - \frac{c}{\gamma_0^2}\int\frac{\delta\gamma}{\gamma_0}\,dt \end{aligned} \tag{12}$$

where $u = c\beta_{z0}$ and z_o are respectively the initial longitudinal velocity and the initial coordinate of the electron.

Substituting (12) into (9), we have

$$\begin{aligned} \frac{d}{dt}\left(\frac{\delta\gamma}{\gamma_0}\right) \approx & -\left(\frac{|e|}{\gamma_0 mc}\right)^2 \frac{E_r B_w}{K_w} \\ & \times \cos\left(\Delta\omega t + \phi_0\right) - \left(\frac{|e|}{\gamma_0 mc}\right)^2 \\ & \times \frac{E_r B_w \omega}{K_w \gamma_0^2} \sin\left(\Delta\omega t + \phi_0\right) \int \frac{\delta\gamma}{\gamma_0}\,dt \\ & -\left(\frac{|e|}{mc}\right)^2 \frac{E_r}{\omega_r} \Big\{ \cos(\xi_{r0} + \delta\xi_r) \\ & \times \int \sin\left(\xi_{r0} + \delta\xi_r\right) dE_r \\ & - \sin\left(\xi_{r0} + \delta\xi_r\right) \int \cos\left(\xi_{r0} + \delta\xi_r\right) \\ & \times dE_r \Big\} \end{aligned} \tag{13}$$

where

$$\begin{aligned}
\Delta\omega &= K_w u - \omega_r(1-\beta_{z0})\\
\phi_0 &= (K_w + K_r)z_0 + \phi_w + \phi_r,\\
\omega &= c(K_r + K_w)\\
\xi_{r0} &= -\omega_r(1-\beta_{z0})t + \phi_r\\
\delta\xi_r &= -\frac{\omega_r}{\gamma_0^2}\int\frac{\delta\gamma}{\gamma_0}\,dt
\end{aligned}\tag{14}$$

Equation (13) is the basic equation of our energy model. We notice that $\delta\gamma/\gamma_0$ appears on both sides of the equation but it contains different physical meaning. On the left side of the equation, it represents the energy conversion rate of the electron. On the right hand side of the equation, because of (11) and (12), it represents the change of the state of motion of the electron. In other words, we describe the action and reaction of the electron and the field in the stimulated emission process of a free electron by one simple equation. By doing so we have not only greatly simplified the calculation steps but also arrived at a theoretical model that presents a clear physical picture. Based on this basic equation we shall calculate the energy conversion efficiencies for small signals and for strong signals.

III. Small Signal Condition

For small signals the amplitude E_r of the radiation field electric vector may be approximately regarded as a constant, i.e., $E_r \approx E_o$. Then, (13) simplifies to

$$\begin{aligned}
\frac{d}{dt}\left(\frac{\delta\gamma}{\gamma_0}\right) \approx &-\left(\frac{|e|}{\gamma_0 mc}\right)^2\frac{E_0 B_w}{K_w}\\
&\times\cos(\Delta\omega t+\phi_0) - \left(\frac{|e|}{\gamma_0 mc}\right)^2\\
&\times\frac{E_0 B_w \omega}{K_w \gamma_0^2}\sin(\Delta\omega t+\phi_0)\\
&\times\int\frac{\delta\gamma}{\gamma_0}\,dt
\end{aligned}\tag{15}$$

By integrating both sides of (15), we have

$$\begin{aligned}
\frac{\delta\gamma}{\gamma_0} \approx &-\frac{G_{wr}{}'}{\Delta\omega}\{\sin(\Delta\omega t+\phi_0)-\sin\phi_0\}\\
&-D_{wr}\int\sin(\Delta\omega t+\varphi_0)\\
&\times\left[\int_0^t \delta\gamma/\gamma_0\,dt'\right]dt
\end{aligned}\tag{16}$$

where

$$G_{wr} \equiv \left(\frac{|e|}{\gamma_0 mc}\right)^2 \frac{E_0 B_w}{K_w}, \quad D_{wr} \equiv G_{wr} \frac{\omega}{\gamma_0^2} \tag{17}$$

To solve (16), we expand $\delta\gamma$ into a series

$$\delta\gamma = \delta\gamma_1 + \delta\gamma_2 + \cdots = \sum_n \delta\gamma_n \tag{18}$$

where $\delta\gamma_1 \propto E_0$, $\delta\gamma_2 \propto E_0^2 \cdots\cdots$ Substituting into (16), we obtain a series of coupling equations for different orders of $\delta\gamma_n$:

$$\begin{aligned}
\frac{\delta\gamma_1}{\gamma_0} &= \frac{G_{wr}}{\Delta\omega}\{\sin\phi_0 - \sin(\Delta\omega t + \phi_0)\} \\
\frac{\delta\gamma_2}{\gamma_0} &= -D_{wr}\int \sin(\Delta\omega t + \phi_0)\left[\int_0^t \frac{\delta\gamma_1}{\gamma_0}\,dt'\right]dt \\
&\cdots\cdots \\
\frac{\delta\gamma_n}{\gamma_0} &= -D_{wr}\int \sin(\Delta\omega t + \phi_0) \\
&\quad \times \left[\int_0^t \frac{\delta\gamma_{n-1}}{\gamma_0}\,dt'\right]dt
\end{aligned} \tag{19}$$

Equation (19) describes the energy change of a single relativistic electron interacting with the Wiggler magnetic field and the radiation field. Since the initial phase of the electron is a random number between 0 and 2π and consequently each electron has a different energy change, an understanding of the macroscopic effects of the electron beam must be obtained by finding the weighted statistical mean based on the initial phases of the electrons.

From (19), we have

$$\begin{aligned}
\left\langle \frac{\delta\gamma_1}{\gamma_0} \right\rangle_{\phi_0} &\equiv \frac{1}{2\pi}\int_0^{2\pi} \frac{\delta\gamma_1}{\gamma_0}\,d\phi_0 = 0 \\
\left\langle \frac{\delta\gamma_2}{\gamma_0} \right\rangle_{\phi_0} &= \frac{G_{wr} D_{wr}}{\Delta\omega^3}\Big\{1 - \cos\Delta\omega t \\
&\quad - \frac{1}{2}\Delta\omega t \sin\Delta\omega t\Big\}
\end{aligned} \tag{20}$$

Equation (20) shows that, according to the initial phase of the electrons entering the Wiggler field, some electrons will gain energy and be accelerated and other electrons will lose energy and slow down. On the whole the energy of the electron beam remains unchanged. As a result of the beam-field interaction, the beam is spatially focused. Only a spatially focused beam can exchange energy with the radiation field and, under certain initial conditions, amplify the radiation field. This conclusion is in total agreement with those of other theories.

Under energy conservation,the gain of the radiation field is

$$g(t)=\frac{\rho_e\langle\delta\gamma\rangle_{e}mc^2V}{\epsilon_0E_0^2V} \qquad (21)$$

where ρ_e is the macroscopic density of the electron beam, V is the volume of the interaction region, and $\varepsilon_o E_o^2$ V is the initial energy of the radiation field. Substituting (20) into (21), we have

$$g(t)=\frac{2\rho_e|e|^4B_w^2}{\epsilon_0 cK_w m^3\gamma_0^3\Delta\omega^3}\Big\{1-\cos\Delta\omega t - \frac{\Delta\omega t}{2}\sin\Delta\omega t\Big\} \qquad (22)$$

The gain curve predicted by (22) are also in agreement with those obtained from other theories. Obviously the calculation is much simpler using our energy model.

IV. Strong Signal Condition

For strong signals the effects of the electric field vector amplitude E_r on the energy of the relativistic electron beam can no longer be neglected. That is, we must consider the strong signal situation on the basis of (13).

In this section we shall first derive the functional relationship between the radiation intensity and the energy of the electron beam based on energy conservation and then solve the basic equation for the energy conversion efficiency for strong signals and interpret the saturation phenomenon.

1. Changes in radiation intensity

Let the energy densities of the radiation field and the relativistic electron beam be W_r and W_e respectively:

$$\begin{aligned} W_r &= \epsilon_0 E_r^2 \\ W_e &= \rho_e\bar{\gamma}mc^2 \end{aligned} \qquad (23)$$

where $\bar{\gamma}$ is the average of the energy parameter. The total energy density is $W=W_r+W_e$. Under energy conservation, we have

$$\begin{aligned} dW &= dW_r+dW_e \\ &= \epsilon_0 d(E_r^2)+\rho_e mc^2 d(\bar{\gamma})=0 \end{aligned} \qquad (24)$$

The solution of (24) is

$$E_r^2-E_{r0}^2=-\frac{\rho_e mc^2}{\epsilon_0}(\bar{\gamma}-\gamma_0)$$

$$=\frac{\rho_e\gamma_0 mc^2}{\epsilon_0}\left(\frac{\overline{\delta\gamma}}{\gamma_0}\right)$$

$$E_r^2=E_{r0}^2\left\{1+\frac{W_{e0}}{W_{r0}}\left(\frac{\overline{\delta\gamma}}{\gamma_0}\right)\right\} \qquad (25)$$

where E_{ro} is the initial amplitude of the radiation field electric vector, $W_{e0}=\rho_e\gamma_0 mc^2$, $W_{r0}=\epsilon_0 E_{r0}^2$ represent respectively the initial energy densities of the electron beam and the radiation field. Since $W_{e0}(\delta\gamma/\gamma_0)\ll W_{r0}$, always holds true for strong signals, E_r may be approximated by

$$E_r\approx E_{r0}+\alpha\left(\frac{\overline{\delta\gamma}}{\gamma_0}\right)\equiv E_{r0}+\delta E_r \qquad (26)$$

$$\alpha=\frac{\rho_e\gamma_0 mc^2}{2\epsilon_0 E_{r0}} \qquad (27)$$

Equations (25) and (26) describe the radiation intensity and the electric field vector amplitude as functions of the electron energy. We shall now discuss the inverse process or the effects of the radiation field on the energy conversion efficiency of the electron.

2. Basic equation and its solution for strong signals

Substituting (26) into (13), we obtain the energy conversion equation of the relativistic electron under the strong signal condition:

$$\frac{d}{dt}\left(\frac{\delta\gamma}{\gamma_0}\right)=-\left(\frac{|e|}{\gamma_0 mc}\right)^2\frac{B_w}{K_w}\left(E_{r0}+\alpha\frac{\overline{\delta\gamma}}{\gamma_0}\right)$$
$$\times\cos(\Delta\omega t+\phi_0)-\left(\frac{|e|}{\gamma_0 mc}\right)^2\frac{B_w\omega}{K_w\gamma_0^2}\Big(E_{r0}$$
$$+\alpha\frac{\overline{\delta\gamma}}{\gamma_0}\Big)\sin(\Delta\omega t+\phi_0)\int\frac{\delta\gamma}{\gamma_0}dt$$
$$-\left(\frac{|e|}{\gamma_0 mc}\right)^2\frac{\alpha}{\omega_r}\left(E_{r0}+\alpha\frac{\overline{\delta\gamma}}{\gamma_0}\right)$$
$$\times\Big\{\cos(\xi_{r0}+\delta\xi_r)\int\sin(\xi_{r0}+\delta\xi_r)d\left(\frac{\overline{\delta\gamma}}{\gamma_0}\right)$$
$$-\sin(\xi_{r0}+\delta\xi_r)\int\cos(\xi_{r0}+\delta\xi_r)d\left(\frac{\overline{\delta\gamma}}{\gamma_0}\right)\Big\} \qquad (28)$$

The physical interpretation of (28) is the same as that under the small signal condition except that Eq. (28) shows the effects of the radiation field change on the electron energy conversion efficiency more explicitly.

To find a solution for (28), we shall first consider the interaction of the relativistic electron with the Wiggler field and the radiation field. After a relativistic electron enters the Wiggler, its state of motion will be changed because of the modulation effect of the Wiggler. If a strong signal is injected into the laser at this time, then, under certain condition there will be an energy transfer from the electron beam to the radiation field and the amplified signal will continue to interact with the electron beam and cause further energy conversion and signal amplification. This interaction continues until the field and the electron reach an equilibrium. This is usually known as the gain saturation. In view of this, we expand the electric field change δE_r and the electron energy parameter change $\delta\gamma$ into series:

$$\begin{gathered} E_r = E_{r0} + \delta E_r = E_{r0} + \delta E_{r1} + \delta E_{r2} + \cdots \\ \gamma = \gamma_0 - \delta\gamma = \gamma_0 - (\delta\gamma_1 + \delta\gamma_2 + \cdots) \end{gathered} \tag{29}$$

The interaction process can then be represented conveniently with the following relations

$$\begin{array}{ll} E_{r0} \to \dfrac{\delta\gamma_1}{\gamma_0}, & \delta E_{r1} = \alpha\left(\dfrac{\overline{\delta\gamma_1}}{\gamma_0}\right) \\ \delta E_{r1} \to \dfrac{\delta\gamma_2}{\gamma_0}, & \delta E_{r2} = \alpha\left(\dfrac{\overline{\delta\gamma_2}}{\gamma_0}\right) \\ \vdots & \vdots \\ \delta E_{rn} \to \dfrac{\delta\gamma_{n+1}}{\gamma_0}, & \delta E_{rn+1} = \alpha\left(\dfrac{\overline{\delta\gamma_{n+1}}}{\gamma_0}\right) \\ \vdots & \vdots \end{array} \tag{30}$$

where the symbol "→" indicates the induced process.

Equations (29) and (30) not only correctly describe the physical process of the field-electron interaction but also circumvented the divergent series problem associated with the strong signal. It is precisely this mathematical difficulty that has complicated the strong signal theories in the past.

Substituting (29) and (30) into (28), we obtain a series of coupling equations in different orders of $\delta\gamma_n/\gamma_0$.

(i) Let

$$\begin{gathered} E_r = E_{r0}, \ \delta\gamma = \delta\gamma_1, \\ \delta E_{r1} = \alpha\left(\frac{\overline{\delta\gamma_1}}{\gamma_0}\right) \end{gathered} \tag{31}$$

then

$$\frac{d}{dt}\left(\frac{\delta\gamma_1}{\gamma_0}\right) = -\left(\frac{|e|}{\gamma_0 mc}\right)^2 \frac{E_{r0}B_w}{K_w}$$
$$\times\cos(\Delta\omega t+\phi_0) - \left(\frac{|e|}{\gamma_0 mc}\right)^2 \frac{E_{r0}B_w\omega}{K_w\gamma_0^2}$$
$$\times\sin(\Delta\omega t+\phi_0)\int \frac{\delta\gamma_1}{\gamma_0}\,dt \qquad (32)$$

Since the third and the fourth terms on the right hand side of (28) are non-resonant terms, they are neglected in the following calculations. The results show that this is a reasonable approximation.

The solution of (32) can be easily written as

$$\frac{\overline{\delta\gamma_1}}{\gamma_0} \equiv \left\langle\frac{\delta\gamma_1}{\gamma_0}\right\rangle_{av} = \frac{A_1B_1}{\Delta\omega^3}\left\{1-\cos\Delta\omega t\right.$$
$$\left.-\frac{\Delta\omega t}{2}\sin\Delta\omega t\right\} \qquad (33)$$

where

$$A_1 = \left(\frac{|e|}{\gamma_0\omega c}\right)^2 \frac{E_{r0}B_w}{K_w},\quad B_1 = A_1\frac{\omega}{\gamma_0^2} \qquad (34)$$

δE_{r1} can then be written as

$$\delta E_{r1} = \alpha\left\langle\frac{\delta\gamma_1}{\gamma_0}\right\rangle_{av} = \frac{\alpha A_1B_1}{\Delta\omega^3}\left\{1-\cos\Delta\omega t\right.$$
$$\left.-\frac{1}{2}\Delta\omega t\sin\Delta\omega t\right\} \qquad (35)$$

(ii) Let

$$E_r = E_{r0}+\delta E_{r1},\ \frac{\delta\gamma}{\gamma_0} = \frac{\delta\gamma_1}{\gamma_0} + \frac{\delta\gamma_2}{\gamma_0},$$

$$\text{and}\qquad \delta E_{r2} = \alpha\left(\frac{\overline{\delta\gamma_2}}{\gamma_0}\right),$$

we then have

$$\frac{d}{dt}\left(\frac{\delta\gamma_2}{\gamma_0}\right) = -\frac{A_1\delta E_{r1}}{E_{r0}}\cos(\Delta\omega t+\phi_0)$$
$$-\frac{B_1\delta E_{r1}}{E_{r0}}\sin(\Delta\omega t+\phi_0)$$
$$\times\int\frac{\delta\gamma_2}{\gamma_0}\,dt \qquad (36)$$

Let $\delta\gamma_2 = \delta\gamma_2' + \delta\gamma_2'' + \cdots$, where $\delta\gamma_2' \propto \delta E_{r1}, \delta\gamma_2'' \propto (\delta E_{r1})^2 \cdots\cdots$

We then have

$$\frac{d}{dt}\left(\frac{\delta\gamma_2'}{\gamma_0}\right) = -\frac{A_1 \delta E_{r1}}{E_{r0}} \cos(\Delta\omega t + \phi_0)$$
$$= -\frac{A_2}{\Delta\omega^3}\left\{1 - \cos\Delta\omega t - \frac{\Delta\omega t}{2}\sin\Delta\omega t\right\}\cos(\Delta\omega t + \phi_0) \tag{37}$$

$$\frac{d}{dt}\left(\frac{\delta\gamma_2''}{\gamma_0}\right) = -\frac{B_1 \delta E_{r1}}{E_{r0}} \sin(\Delta\omega t + \phi_0) \times \int \frac{\delta\gamma_2'}{\gamma_0}\,dt$$
$$= -\frac{B_2}{\Delta\omega^3}\left\{1 - \cos\Delta\omega t - \frac{1}{2}\Delta\omega t \sin\Delta\omega t\right\} \times \sin(\Delta\omega t + \phi_0)\int \frac{\delta\gamma_2'}{\gamma_0}\,dt \tag{38}$$

where

$$A_2 = \frac{\alpha A_1^2 B_1}{E_{r0}}, \quad B_2 = \frac{\alpha A_1 B_1^2}{E_{r0}} \tag{39}$$

The solution of (37) is

$$\frac{\delta\gamma_2'}{\gamma_0} = -\frac{A_2}{\Delta\omega^4}\{\sin(\Delta\omega t + \phi_0) - \sin\phi_0\} + \frac{5A_2}{16\Delta\omega^4}\{\sin(2\Delta\omega t + \phi_0) - \sin\phi_0\} + \frac{A_2 t}{2\Delta\omega^3}\cos\phi_0 - \frac{A_2 t}{8\Delta\omega^3} \times \cos(2\Delta\omega t + \phi_0) - \frac{A_2 t^2}{8\Delta\omega^2}\sin\phi_0 \tag{40}$$

Substituting (40) into (38) and finding the mean with respect to ϕ_0, we have

$$\left\langle \frac{\delta\gamma_2''}{\gamma_0} \right\rangle_{t_0} = \frac{A_2B_2}{\Delta\omega^5} \Big\{ 1 - \cos\Delta\omega t$$

$$- \frac{11}{16}\Delta\omega t \sin\Delta\omega t + \frac{3}{16}(\Delta\omega t)^2 \cos\Delta\omega t$$

$$+ \frac{5}{128}(\Delta\omega t)^2 + \frac{1}{48}(\Delta\omega t)^3 \sin\Delta\omega t$$

$$+ \frac{1}{192}(\Delta\omega t)^4 - \frac{49}{256}(1 - \cos 2\Delta\omega t)$$

$$+ \frac{1}{384}(\Delta\omega t)^4 \cos 2\Delta\omega t$$

$$- \frac{5}{192}(\Delta\omega t)^3 \sin 2\Delta\omega t$$

$$- \frac{7}{64}(\Delta\omega t)^2 \cos 2\Delta\omega t$$

$$+ \frac{29}{128}\Delta\omega t \sin 2\Delta\omega t \Big\} \qquad (41)$$

and

$$\delta E_{r2} = \alpha \left\langle \frac{\delta\gamma_2}{\gamma_0} \right\rangle_{t_0} \approx \alpha \left\langle \frac{\delta\gamma_2''}{\gamma_0} \right\rangle_{t_0} \qquad (42)$$

Using this method, we may solve for (38) to any order of correction. For the purpose of problems discussed here, the above solution is already sufficient.

3. Strong signal saturation

For the sake of discussion, we expand the cosΔωt and sinΔωt terms in the δE_r expression into series and keep the $(\Delta\omega t)^6$ terms. Since $\Delta\omega t \ll 1$, this approximation is reasonable.

Then, δE_{r1} and δE_{r2} may be written as

$$\delta E_{r1} \approx \frac{\alpha A_1 B_1}{\Delta\omega^5} \frac{(\Delta\omega t)^4}{24} \left\{ 1 - \frac{1}{15}(\Delta\omega t)^2 \right\} \qquad (43)$$

$$\delta E_{r2} \approx \frac{\alpha A_2 B_2}{\Delta\omega^9} \frac{(\Delta\omega t)^4}{160} \qquad (44)$$

and

$$\frac{\delta E_{r1}}{\delta E_{r2}} \approx \frac{\epsilon_n^2 \gamma_n^4 C^4 K_w^4}{W_{c0}^2 B \omega^4 K_r^2 \left(\frac{|e|}{\gamma_0 mc} \right)^2} \times (\Delta\omega t)^4 [15 - (\Delta\omega t)^2] \qquad (45)$$

From (45) it is obvious that $\delta E_{r2} \ll \delta E_{r1}$. That is, as the radiation field intensity increases, it gradually receive less and less energy from the relativistic electron beam and the amplification of the radiation field therefore has an upper limit. This is the saturation phenomenon mentioned earlier. A discussion of the saturation problem will be published later.

4. Gain under the strong signal condition

From (25), the radiation intensity is

$$I=I_0\left\{1+\frac{W_{s0}}{W_{r0}}\left\langle\frac{\delta\gamma}{\gamma_0}\right\rangle_{ss}\right\} \qquad (46)$$

If G is the gain coefficient, we have

$$I=I_0\exp(G) \qquad (47)$$

Combining (46) and (47) leads to the following expression for G:

$$G=\ln\left[1+\frac{W_{s0}}{W_{r0}}\left\langle\frac{\delta\gamma}{\gamma_0}\right\rangle_{ss}\right] \qquad (48)$$

Since $\langle\delta\gamma/\gamma_0\rangle_{ss}<1,\ W_{s0}\ll W_{r0},$ G may be approximated by

$$G\approx\frac{W_{s0}}{W_{r0}}\left(\frac{\delta\gamma}{\gamma_0}\right)_{ss}-\frac{1}{2}\left[\frac{\omega_{s0}}{\omega_{r0}}\left\langle\frac{\delta\gamma}{\gamma_0}\right\rangle_{ss}\right]^2$$
$$+\frac{1}{3}\left[\frac{W_{s0}}{W_{r0}}\left\langle\frac{\delta\gamma}{\gamma_0}\right\rangle_{ss}\right]^3-\cdots\cdots \qquad (49)$$

A comparison with the small signal gain show that G is no longer a linear function of $\langle\delta\gamma\rangle_{ss}$ This again demonstrates the saturation effect under the strong signal condition.

In this work we have established an energy model for the free electron laser based on the law of energy conservation. We have successfully applied the model to treat small signals and strong signals. The advantages of the model are that it is simple, intuitive, and widely applicable. In the future we shall apply the model to the study of parameter variation, harmonic radiation and short wavelength radiation.

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9698/7358
CSO: 4008/92

APPLIED SCIENCES

DETECTOR FOR PARTICLES OF LASER SCANNING TRANSFUSION DEVELOPED

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 13 No 2, 20 Feb 86 p 79

[Article by Yu Jie [0060 2638] of the Jilin Institute of Research]

[Text] The Jilin Institute of Research and the Air Force Military Medicine College of the PLA have jointly developed a model JSW-85 laser scanning particle detector for transfusion. The instrument has recently passed the technical evaluation conducted by the Air Force Health Department in Jilin.

Transfusion is an important clinical technique. With the increasing use of transfusion in medicine, attention has been directed to pathological phenomena caused by particles in the transfusion such as capillary blood vessel blockage, local edema or necrosis, thrombus caused by blood cells adhered to particles, and venous thrombosis. To date the particle detection methods used in China and abroad cannot effectively control the particles. Hence, there is an urgent need for an accurate, rapid and effective method for controlling the size and number of particles in the transfusion process.

Attendees of the evaluation meeting all agreed that the principle of particle detection by laser scanning is feasible. The JSW-85 laser scanner uses the current technology of laser scanning and converts the light scattered by the particles in the fluid into an electrical signal. The scanner is capable of large area scanning of fluids sealed in the bottles and can automatically count the particles, sound the alarm and reject the unacceptable bottles of fluids. The performance has met the design specifications.

The meeting attendees believed that the new device has opened up a new approach to particle detection, a method not reported before in China and abroad. The device is of great practical value in controlling the quality of the transfusion fluid so that the national pharmaceutical standards are met. The evaluators also recommended that the responsible department should organize a batch production of sample machines so that the design may be finalized in the trial use and the application may be promoted.

9698/12947
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Nd:GLASS LASER HARDENING TECHNIQUE USED FOR FIRST TIME IN INSTRUMENT MANUFACTURE

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 13 No 2, 20 Feb 86 p 70

[Article by Guo Dahao [6753 1129 3185], Yang Yongning [2799 3057 1337], Wu Hongxing [0702 7703 5281], Han Wenhai [7281 2429 3189], and Dai Yusheng [2071 1342 3932] of the Chinese Science and Technology University and Cheng Yunying [4453 0061 5391] of the Hefei Meters General Plant]

[Text] The Nd:glass laser hardening of $_4Cr_{13}$ axle tip technology developed by the Chinese Science and Technology University and the Hefei Meters General Plant has passed the evaluation held on 11 September 1985 at the Chinese Science and Technology University.

Although China has been engaged in the development of laser heat treatment technology and application for some time, CO_2 lasers are used in most cases. The Nd:glass laser hardening technique is still in the experimental stage.

Using a pulsed Nd:glass laser, the Chinese Science and Technology University carried out hardening tests of the axle tips of the $_4Cr_{13}$ wing shaft and the internal magnetic steel axle in steam flowmeters manufactured by the Hefei Meters General Plant. The technical specifications are determined to be as follows. The parts are first blackened with smoke and the axial tip is then aligned with the laser beam and each part is exposed to one laser pulse of 4.2 ms at a power density of $6\text{-}8 \times 10^4$ W/cm^2.

With the laser hardening, the surface hardness is controlled in the H_v 750-560 range, the microstructure of the phase hardened zone is $M_{implicit} + A_{residual} + K_{undissolved}$, the hardness of the transition zone is 560-240, the microstructure $M + A_{residual} + K + P$, the matrix is nodular P, and the microhardness is 240. The average depth of the hardened layer is 0.1 mm and the maximum hardened depth at the tip is 0.3 mm. The surface residual stress is compressive and equals 15-60 kg/mm^2.

The hardening prevents the parts from oxidation, carbon loss and deformation, and keeps the surface clean. No post heat treat polishing is required on the hardened parts. All heat treated axial tips with the laser met the technical specification and the quality is improved. The laser technique has solved the dificult problem of inadequate hardness in conventional flame hardening and high frequency induction hardening technique used by the plant.

In the 6 months since March 1985, several hundreds flow meter with laser hardened parts have been assembled and distributed to the users. The service record has been good and axial tip damage related malfunctions have not been reported. This is the first time in China that Nd:glass laser hardening has been used in production.

Since Nd:glass lasers are characterized by their high power pulses, compact structure, stable and reliable operation, ease of use and low investment, they are potentially very useful for small area heat treatment. All the attendees at the evaluation meeting recommended broadening the scope of application.

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APPLIED SCIENCES

THEORETICAL ANALYSIS OF SINGLE FREQUENCY He-Ne LASERS

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 13, No 7, 20 Jul 86 pp 392-396

[Article by Li Shangyi [2621 1424 5030], Xiao Jianning [5135 1696 1337], and Cheng Daguang [4453 1129 0342] of the Beijing Scientific Instrument Factory]

[Text] Abstract: A single frequency high output power He-Ne laser was obtained with inhomogeneous longitudinal magnetic field and high gas pressure, it has high frequency stability and a coherence length of greater than 14 meters. This paper presents the theoretical analysis on the operation mechanism.

A high power single frequency output may be obtained from a conventional He-Ne laser by applying an inhomogeneous longitudinal magnetic field under a high gaseous pressure. An experimental study is described in Ref. 1. The laser discharge tube is about 1 m long, the cavity length is 1,140 mm, and the single frequency output may reach 18-20 mW. The coherence length, as measured by the Institute of Physics of the Chinese Academy of Sciences, is greater than 14 m. The frequency drift measured by beating with an iodine stabilized He-Ne laser is about 1-2 MHz per second. Figure 1 shows a spectrum photo during the beating experiment, and figure 2 shows the single frequency signal taken from a scanning interferometer. The effects of the longitudinal magnetic field have been studied in Ref. 1 in terms of the gain changes. It was also observed experimentally that the single frequency output of this type of laser occurs exactly at the intersection of the left and right-polarized gain curves after the gain curve undergoes a Zeeman splitting caused by the longitudinal magnetic field. A cross-section oscillation interpretation was then proposed. In this paper, further theoretical analysis is given.

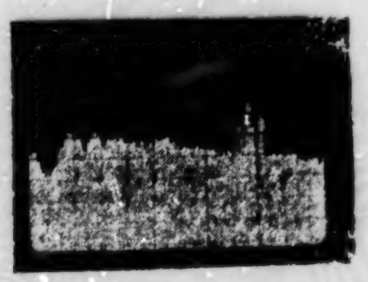

Fig. 1.

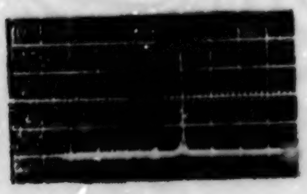

Fig. 2.

By applying a longitudinal magnetic field outside the laser discharge tube, the resulting Zeeman splitting causes the gain curve to split into two branches corresponding to the left and right-polarization. The two branches have equal amplitude and their intersection corresponds to the sum of the two polarizations, or a linear polarization. The linear polarization may pass through the Brewster window and the circularly polarized components are naturally filtered out by the Brewster window. In this type of laser the Brewster window itself acts as an excellent mode selector.

The purpose of applying an inhomogeneous longitudinal magnetic field is to suppress the gain of the 3.39 μm radiation and improve the lienarity of the laser discharge tube. It provides a much higher output of single longitudinal mode than the homogeneous magnetic field technique reported in the literature.[2,3]

Experimentally we found that a stable single frequency output was obtained at a magnetic field of 65.9 G without the use of temperature and frequency stabilization. Based on the above, it may appear that a single frequency output only requires the application of a longitudinal magnetic field. Results of our extensive experiments show that it also requires a high gaseous pressure. And this is the main subject of this paper.

At normal pressure a conventional He-Ne laser is inhomogeneously broadened. The small signal gain[4] is given by

$$G_i^0(\nu) = G_i^0(\nu_0)e^{-4\ln 2\left(\frac{\nu-\nu_0}{\Delta\nu_D}\right)^2} \qquad (1)$$

under optimum discharge conditions, the gain is

$$G_i^0(\nu_0) \approx 8\times 10^{-4}\frac{1}{d}$$

In the presence of a 240 MHz Zeeman splitting, the gain curve given by (1) is convoluted. Quantitative analysis yields the degree of overlapping of the two gain curves corresponding to the left and right circularly polarized light. To simplify the calculation, we introduce the concept of an effective gain curve. When a linear function $g(\nu,\nu_0)$ is replaced by a rectangular spectral line $g'(\nu,\nu_0)$ and the height of the rectangular spectral line is made equal to that of the spectral line envelop at its central point, the area enclosed by rectangular spectral line will be equal to the area enclosed by the original spectral line. For a homogeneously broadened spectral line, the equivalent linewidth is

$$\delta\nu = \frac{\pi}{2}\Delta\nu_F \qquad (2)$$

where $\Delta\nu_F$ is equal to $\Delta\nu_H$ of the homogeneously broadened line. For an inhomogeneously broadened Gaussian line, we have

$$\delta\nu = \frac{1}{2}\left(\frac{\pi}{\ln 2}\right)^{\frac{1}{2}}\Delta\nu_F \qquad (3)$$

where $\Delta\nu_F$ refers to $\Delta\nu_D$ of a conventional He-Ne laser.

Based on this principle, we change the gain curve of the left circularly polarized light to an equivalent rectangular gain curve and call it P(t). Then the convolution of the two gain curves after Zeeman splitting changes from that shown in Figure 3 to the situation shown in Figure 4. From a mathematical point of view, the convolution calculation for Figure 4 is much easier. The equivalent linewidth at normal pressure is

$$\delta\nu = \frac{1}{2}\left(\frac{\pi}{\ln 2}\right)^{\frac{1}{2}} \Delta\nu_D$$

With $\Delta\nu_D$ being 1500 MHz, we have

$$\delta\nu = 1600\,\mathrm{MHz}_{\circ}$$

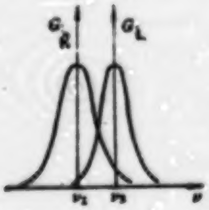

Fig. 3.

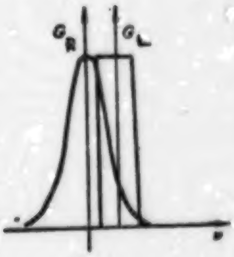

Fig. 4.

The convolution of equation (1) with the 240 MHz Zeeman splitting of a 1,600 MHz wide rectangular equivalent gain curve is

$$G_i^0(\nu_0) * P(t)$$

Let $(\nu-\nu_0) = t$, we have

$$\begin{aligned} G_i^0(t) * P(t) &= \int_{240-800}^{240+800} G_i^0(\nu_0) e^{-(2\sqrt{\ln 2})^2\left(\frac{t}{\Delta\nu_D}\right)^2} \\ &\times dt = \frac{G_i^0(\nu_0)\,\Delta\nu_D}{(2\sqrt{\ln 2})} \int_{-560}^{1040} e^{\frac{-(2\sqrt{\ln 2})^2}{\Delta\nu_D^2} t^2} \\ &\times d\,\frac{2\sqrt{\ln 2}}{\Delta\nu_D}\,t \end{aligned} \qquad (4)$$

Let $\frac{2\sqrt{\ln 2}}{\Delta\nu_D}t = k$ (4) becomes

$$G_i^0(t)*P(t)=\frac{G_i^0(\nu_0)\,\Delta\nu_D}{2\sqrt{\ln 2}}\int_{-960}^{1040}e^{-k^2}\,dk$$
$$=\frac{G_i^0(\nu_0)\,\Delta\nu_D}{2\sqrt{\ln 2}}\left[k\left(1-\frac{k^2}{1!3}+\frac{k^4}{2!5}-\frac{k^6}{3!7}+\cdots\right)\right]_{-300}^{1040} \qquad (5)$$

Keeping only the first three terms in the expansion, we have

$$G_i^0(t)*P(t)=1716.6845\times10^{-4}\ (\mathrm{MHz/mm}) \qquad (6)$$

(6) is the convolution of the two circularly polarized gain curves separated by 240 MHz at normal pressure.

At high pressure we treat the problem with the principle of homogeneous broadening. At a pressure of 6 Torr, the spectral width is $\Delta\nu_L=\alpha\cdot P$, For a conventional He-Ne laser, $\alpha=100\,\mathrm{MHz/Torr}$, and the width is

$$\Delta\nu_L=100\times6=600\,\mathrm{MHz},$$

The width of the hole burned in the spectrum is $\Delta\nu_L\sqrt{\frac{I_\nu}{I_s}}$, Since I_V/I_S is about 3 for a conventional He-Ne laser,[4] we have

$$\Delta\nu_L\sqrt{1+\frac{I_\nu}{I_s}}=1200\,\mathrm{MHz}.$$

Therefore, the width of the hole in each longitudinal mode can almost cover the entire linewidth of the gain curve. With the burn holes overlapping, the saturation of each longitudinal mode will affect all other longitudinal modes in the gain curve. Since homogeneous broadening is associated with homogeneous saturation, the gain curve is reduced and the linewidth is compressed from 1,500 MHz to 600 MHz. Figure 5 shows the mode spectrum of a He-Ne laser taken at a high pressure but without longitudinal inhomogeneous magnetic field. In our device the five longitudinal modes are separated by 120 MHz and the entire linewidth is 600 MHz. Furthermore, the pressure broadening is also 600 MHz, exactly equal to the spectral width shown in Figure 5. This again shows that the laser may be treated as homogeneously broadened. The gain can therefore be written as

$$G_H^0(\nu)=G_H^0(\nu_0)\frac{\left(\frac{\Delta\nu_H}{2}\right)^2}{(\nu-\nu_0)^2+\left(\frac{\Delta\nu_H}{2}\right)^2} \qquad (7)$$

Fig. 5.

The degree of overlapping of the two gain curves for the left and right circularly polarized light may be evaluated by computing the gain curve convolution at high pressure for 240 MHz Zeeman splitting using Eq. (7). But first we must estimate $G_H^0(\nu_0)$ in (7). For a given laser tube diameter and wavelength, the transition from inhomogeneous broadening to homogeneous broadening may be treated as follows. From Ref 4 we have

$$G_H^0(\nu_0) = \Delta n^0 \frac{\lambda_n^2 A_m}{4\pi^2 \Delta\nu_H} \qquad (8)$$

$$G_i^0(\nu_0) = \Delta n^0 \frac{\lambda_n^2 A_m}{4\pi \Delta\nu_D}\left(\frac{\ln 2}{\pi}\right)^{\frac{1}{2}} \qquad (9)$$

Hence

$$\frac{G_i^0(\nu_0)}{G_H^0(\nu_0)} = \frac{\sqrt{\ln 2}}{\Delta\nu_D\sqrt{\pi}} \times \Delta\nu_H \pi = 0.59 \qquad (10)$$

Since

$$G_i^0(\nu_0) \approx 3 \times 10^{-4} \frac{1}{d}$$

we have

$$G_H^0(\nu_0) \approx 5 \times 10^{-4} \frac{1}{d} \qquad (11)$$

Because the broadening at high pressure is homogeneous, the line shape of the gain curve may be assumed Lorentzian. The equivalent linewidth is therefore

$$\delta\nu = \frac{\pi}{2} \Delta\nu_H = 942\,\mathrm{MHz}$$

With a 240 MHz Zeeman splitting, the convolution of the gain curve and the equivalent gain curve is

$$
\begin{aligned}
&G^{0}_{H}(\nu)*P(t)=G^{0}_{H}(t)*P(t)\\
&=\int_{240-471}^{240+471} G^{0}_{H}(\nu_0)\frac{\left(\frac{\Delta\nu_H}{2}\right)^2}{t^2+\left(\frac{\Delta\nu_H}{2}\right)^2}dt\\
&=G^{0}_{H}(\nu_0)\times\left(\frac{\Delta\nu_H}{2}\right)^2\int_{-231}^{711}\frac{1}{t^2+\left(\frac{\Delta\nu_H}{2}\right)^2}\\
&\times dt=G^{0}_{H}(\nu_0)\times\left(\frac{\Delta\nu_H}{2}\right)\\
&\times\left[\operatorname{arc\,tg}\frac{t}{\left(\frac{\Delta\nu_H}{2}\right)}\right]_{-231}^{711}\\
&=1244.36\times10^{-4}(\mathrm{MHz/mm}) \qquad (12)
\end{aligned}
$$

where $\nu-\nu_0=t$,

By comparing the results of (6) and (12), one can see that the degree of overlapping is clearly greater at higher pressure. Taking into account the linewidths at normal pressure and at high pressure (1500 MHz and 600 MHz respectively), we plot the gain curve splitting on the same scale. Figure 6 shows the 240 MHz splitting of the 1500 MHz wide gain curve at normal pressure and Figure 7 shows the 240 MHz splitting of the 600 MHz wide gain curve at high pressure. The effect of the high pressure is to separate the Zeeman split gain curves more widely.

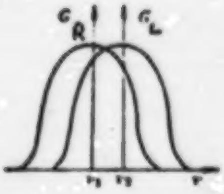

Fig. 6.

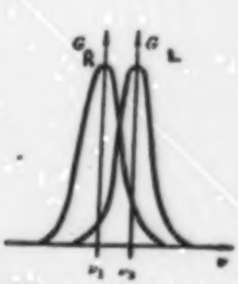

Fig. 7.

In Figure 7, the gain of the two circular polarizations differs by a great amount except at the intersection. The wave at the intersect is therefore highly linearly polarized and may go through the Brewster window to produce a single frequency mode. Waves away from the intersect, such as those at ν_1 and ν_2, are filtered out by the Brewster window. In Figure 6 the gain difference between the left and right polarized waves at a given frequency is small over a wide range of frequency. Waves away from the intersect frequency also show some linear polarization and may also pass the Brewster window. This is why Zeeman splitting at normal pressure cannot produce a single frequency mode.

The conclusion drawn from (6) and (12) may be verified with other method as well. In Figure 8 the 1500 MHz wide gain curve at normal pressure is drawn as its rectangular equivalent gain curve and the 240 MHz Zeeman splitting causes an overlapping of the two circular polarizations (shaded region). The same graphical representation is made for the 600 MHz gain curve at high pressure in Figure 9. A comparison of Figure 8 and 9 shows that the overlapping area at high pressure is much smaller than that at normal pressure, consistent with the conclusion above.

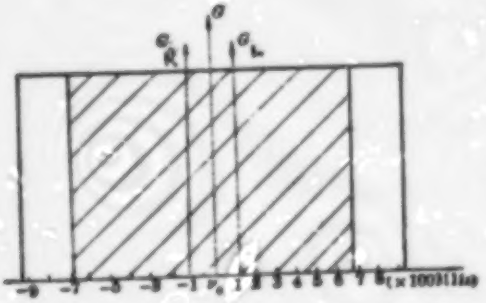

Fig. 8.

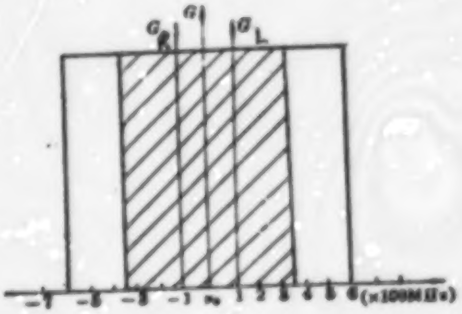

Fig. 9.

Conclusion

1. The application of a longitudinal magnetic field causes a Zeeman splitting of the gain curve. At the intersect of the gain curves of the left- and right-circularly polarized waves the oscillaton is linearly polarized and may go through the Brewster window. The circularly polarized waves away from the intersect frequency are filtered out by the Brewster window and the single longitudinal mode oscillation is maintained.

2. The inhomogeneous longitudinal magnetic field suppresses the 3.39 μm output, improves the linearity of the discharge tube, and raises the output power of the single mode.

3. The effect of the high pressure is for an inhomogeneously broadened He-Ne laser to achieve homogeneous broadening via pressure broadening and extensive overlapping of the burn hole. The homogeneous saturation suppresses the line-width and the longitudinal magnetic field then separates the two gain curves to ensure a single frequency output.

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CSO: 4008/92

APPLIED SCIENCES

FREE-ELECTRON LASERS WITH TRAVELLING WAVE FIELD WIGGLER

Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 13, No 7, 20 Jul 86 pp 397-400

[Article by Lu Ruizheng [7120 3843 1767] of the Physics Department, Tongji University, and Lei Shizhan [7191 0099 3277] of the Shanghai Institute of Optics and Fine Mechanics, the Chinese Academy of Sciences]

[Text] Abstract: The working state of Free-electron lasers with travelling wave radiation field wiggler is analyzed, the laser gain is calculated and the conditions for obtaining gains are also analyzed.

The output wavelength of a free-electron laser is related to the relativistic electron energy and the spatial wavelength λ_w of the wiggler by the following relationship:1

$$\lambda_r = \frac{\lambda_w}{2\gamma^2}(1+k^2) \qquad (1)$$

where γ is the ratio of the kinetic energy to the rest mass of the relativistic electron. γ is also known as the relativistic factor and is defined as

$$\gamma = 1/\sqrt{1-v^2/c^2} \qquad (2)$$

where v is the electron velocity. The factor k in (1) is a constant that depends on the wiggler parameters. To obtain a short wavelength laser light, one way is to use a high energy relativistic electron beam, or make γ very large in (1); the second method is to use a wiggler with a short spatial period. Since λ_r is inversely proportional to the square of γ, the first method is more effective. Because of this, not much work has been done in the use of the second method. However, to have a free electron laser in the UV or X-ray regime, the energy of the relativistic electron must be extremely high. For a wiggler wavelength of 3 cm, an X-ray laser requires relativistic electrons of an energy of at least a billion electronvolts and a monochromaticity of better than 0.1 percent.2 Technologically it is very difficult to produce such an electron beam and to do so requires large facilities. The hard-to-meet energy requirements on the electron beam may be avoided by making the spatial period of the wiggler very short. However, the spatial period of conventional static magnetic or electric wigglers cannot be easily made less than 1 cm. To this end, we have proposed3 the use of standing wave radiation field as wigglers to make the spatial period very short. In this paper, we further point out that a wiggler consisting of a high power laser beam propagating in the same direction of the relativistic electron beam can also amplify the free electron laser. Its principle is similar to that of a gas laser or liquid laser using another laser as a light pump.

Let the relativistic electrons be propagating along the z axis with a velocity v. The pumping high power laser pulse (the wiggler) propagates along the z axis with an angular frequency ω_w and a wavevector $\boldsymbol{k}_w = c\omega_w\hat{z}_o$ The magnetic field of the wiggler is $\boldsymbol{B}_w = \nabla \times \boldsymbol{A}_w$, the electric field is $\boldsymbol{E}_w = -\partial \boldsymbol{A}_w/\partial t)$, and the vector potential of the wiggler is

$$\boldsymbol{A}_w = A_w\{\exp[-i(k'_{w}z + \omega'_w t + \varphi_B)] + \exp i(k'_{w}z + \omega'_w t + \varphi_B)\}\hat{e} + C.C. \tag{3}$$

where $\hat{e} = (\hat{x} - i\hat{y})$

$\hat{x}$ and $\hat{y}$ are unit vectors, A_W is the amplitude of the vector potential and φ_B is the initial phase. Based on the Doppler effect, the wavevector k'_W and the angular frequency ω'_W are given by

$$\omega'_w = \frac{(1+\beta_z)\omega_w}{\sqrt{1-\beta_z^2}} \approx 2\gamma\omega_w \tag{4}$$

$$k'_w \approx 2\gamma k_w \tag{5}$$

where $\beta_z = v_z/c$, and V_2 is the z component of the relativistic electron velocity.

The vector potential $\underline{A}_r$ of the radiation field is

$$\boldsymbol{A}_r = A_r\{\exp i(k_r z - \omega_r t + \varphi_r) + \exp[-i(k_r z - \omega_r t + \varphi_r)]\} + C.C. \tag{6}$$

where A_r is the amplitude, $k_r = 2\pi/\lambda_r$, λ_r is the wavelength, is the angular frequency, and ω_r is the initial phase.

The Hamiltonian of the relativistic electron is

$$H = c[(c\boldsymbol{P} - e\boldsymbol{A}) + m_0^2c^2]^{\frac{1}{2}} = \gamma m_0 c^2 \tag{7}$$

where $\underline{P}$ is the canonical momentum and m_o is the rest mass of the electron, c is the speed of light, and e is the electronic charge.

The equations of motion are

$$p_i = -\frac{\partial H}{\partial q_i}$$
$$q_i = \frac{\partial H}{\partial p_i} \qquad (8)$$

where p_i represents the three components of the canonical momentum, and q_i represents the three coordinates of the position.

From (3) and (6)m the Hamiltonian does not contain x and y, therefore,

$$\dot{p}_x = -\frac{\partial^2 H}{\partial x^2} = 0$$
$$\dot{p}_y = -\frac{\partial^2 H}{\partial y^2} = 0 \qquad (9)$$

and the transverse canonical momentum is a constant, determined by the initial conditions. If the electron enters the wiggler with a zero transverse velocity ($v_\perp = 0$), then the constant may be taken to be zero and

$$p_\perp = 0 \qquad (10)$$

This shows that the transverse momentum $\underline{p_\perp}$ may be written as

$$p_\perp = -eA = m_0\beta_\perp c\gamma \qquad (11)$$

where $\beta_\perp = v_\perp / c$ is a unit velocity vector in the transverse direction.

The electron motion in the wiggler is described by the Lorentz equation:

$$\frac{d\gamma}{dt} = -\frac{e}{m_0 c}\,\beta\cdot E \qquad (12)$$

$$\frac{d}{dt}(\gamma\beta) = -\frac{e}{m_0 c}\,[E + c\beta\times B] \qquad (13)$$

From (12) and (13), we have

$$\frac{d}{dt}\,\gamma\beta_z = \frac{d\gamma}{dt} \qquad (14)$$

Integrating (14), we obtain

$$\gamma(1-\beta_z) = \gamma_0(1-\beta_{z0}) \qquad (15)$$

where γ_0 is the relativistic factor when the electron enters the wiggler

$$\gamma_0 = (1-\beta_{z0}^2)^{-\frac{1}{2}}$$
$$\beta_{z0} = v_{z0}/c$$

Here v_{zo} is the longitudinal velocity of the electron upon entering the wiggler. Since the electric field E only has a transverse component, (12) may be written as

$$\frac{d\gamma}{dt} = -\frac{e}{m_0 c}\beta_\perp \cdot E_\perp \qquad (16)$$

Substituting (11) into (16), we have

$$\frac{d\gamma}{dt} = \frac{e^2}{m_0^2 c^3 \gamma} A_\perp \cdot E_\perp \qquad (17)$$

Substituting (3) and (6) into (7) and simplifying the results, we obtain

$$\frac{d\gamma}{dt} = \frac{e^2}{m_0^2 c^3 \gamma} A_w E_r [\sin\theta + \cos\theta] \qquad (18)$$
$$\theta = (2\gamma k_w + k_r)z + (2\gamma\omega_w - \omega_r)t + \varphi_B - \varphi_r$$

Generally speaking the energy change of the electron in the wiggler is not large, we can therefore write γ and θ in the polynomial form:

$$\gamma = \gamma_0 + \delta\gamma_1 + \delta\gamma_2 + \cdots \qquad (19)$$
$$\theta = \theta_0 + \delta\theta_1 + \delta\theta_2 + \cdots$$

where $\delta\gamma_1, \delta\gamma_2 \cdots$ are respectively small quantities of the first, second, ... order in γ.

Substituting (19) into (18), we have the following equation

$$\delta\dot{\gamma}_1 = \frac{e^2}{\gamma_0 m_0^2 c^3} A_w E_r [\sin(\theta_0 + \theta'_0) + \cos(\theta_0 + \theta'_0)] \qquad (20)$$

where

$$\theta_0 = (2\gamma_0 k_w + k_r) c\beta_{z0} t + (2\gamma_0 \omega_w - \omega_r)t$$
$$\theta'_0 = \varphi_B - \varphi_r$$

Integrating (20) to obtain $\delta\gamma_1$, we have

$$\delta\gamma_1 = \frac{e^2 A_w E_r}{\gamma_0 m_0^2 c^3} \times \left[\frac{\sin(\theta_0+\theta'_0)-\cos(\theta_0+\theta'_0)}{2\gamma_0(1+\beta_{z0})\omega_w-(1-\beta_{z0})\omega_r}\right] \tag{21}$$

Here we made the assumption that $\delta\gamma_1 = 0$, at t = 0.

The equation for the second order quantity is

$$\gamma_0\delta\dot{\gamma}_2 = \frac{e^2 A_w E_r}{m_0^2 c^3}[\sin(\theta_0+\theta'_0+\delta\theta) + \cos(\theta_0+\theta'_0+\delta\theta)] - \gamma_0\delta\dot{\gamma}_1 \tag{22}$$

Using the relationship

$$\beta_z = \frac{\delta\gamma}{\gamma_0}(1-\beta_{z0})+\beta_{z0} \tag{23}$$

and (21), δθ may be found:

$$\delta\theta = 2\omega_w\delta\gamma_1(1+\beta_{z0})t \approx 4\omega_w\delta\gamma_1 t \tag{24}$$

Since $\delta\theta \ll \theta_0+\theta'_0$, the trigonometric function in the brackets on the right hand side of (22) may be expanded:

$$\gamma_0\delta\dot{\gamma}_2 = \frac{e^2 A_w E_r}{m_0^2 c^2}[\sin(\theta_0+\theta'_0) - \delta\theta\sin(\theta_0+\theta'_0) + \delta\theta\cos(\theta_0+\theta'_0) + \cos(\theta_0+\theta'_0)] - \gamma_0\delta\dot{\gamma}_1 \tag{25}$$

Integrating (25) with respect to time and finding the mean over the range of $\theta' = 0 \sim 2\pi$, we have the average $\langle\delta\gamma_2\rangle$

$$\langle\delta\gamma_2\rangle = \frac{1}{2\pi}\int_0^{2\pi}\delta\gamma_2\, d\theta'_0 = \mathscr{A}\{\cos\psi+\psi\sin\psi+\sin\psi - \psi\cos\psi-1\} \tag{26}$$

where

$$\mathscr{A} = \left(\frac{2\omega_w e^2 A_w E_r}{\gamma_0 m_0^2 c^3}\right)^2 \times \frac{1}{[2\gamma_0(1+\beta_{z0})\omega_w-(1-\beta_{z0})\omega_r]^2}$$

$$\psi = [2\gamma_0(1+\beta_{z0})\omega_w-(1-\beta_{z0})\omega_r]t$$

The radiation of a free electron laser is converted from the kinetic energy of the electron. If the flux density of the electron beam is n_e, the radiation flux density produced by an electron beam in the wiggler will be

$$I_r = -(\gamma-\gamma_0)m_0c^2n_e = -\langle\delta\gamma_2\rangle m_0c^2n_e \tag{27}$$

Substituting (26) into (27), we arrive at the radiation flux density I_r of the relativistic electron beam

$$I_r = -\mathscr{A}m_0c^2n_e\{\cos\psi+\psi\sin\psi+\sin\psi -\psi\cos\psi-1\} \tag{28}$$

Let the incident radiation flux density be I_o:

$$I_0 = \frac{c}{4\pi}E_r^2 \tag{29}$$

the gain of the free electron laser is defined as

$$G = I_r/I_0 \tag{30}$$

Putting (28) and (29) into (30) and simplify the results, we have

$$G = \mathscr{A}'n_e\{1+\psi\cos\psi-\cos\psi-\psi\sin\psi -\sin\psi\} \tag{31}$$

where

$$\mathscr{A}' = 4\pi m_0c\left(\frac{2\omega_w e^2A_w}{\gamma_0m_0^2c^2}\right)^2 \times\frac{1}{[4\gamma_0\omega_w-(1-\beta_{z0})\omega_r]^3}$$

Since the expression of the gain G contains [sic] the phase factor θ_o, it may take on any value. Finding the mean over the $\theta_o = 0\sim\pi/2$ range, we have

$$G = (\pi-2)\mathscr{A}'n_e \tag{32}$$

From (32), one realizes that the gain G is positive when

$$4\gamma_0\omega_w > (1-\beta_{z0})\omega_r \tag{33}$$

and the gain G is negative when

$$4\gamma_0\omega_w < (1-\beta_{z0})\omega_r \tag{34}.$$

Moreover, since

$$(1-\beta_\infty)\approx\frac{1}{2\gamma_0^2} \tag{85}$$

the relativistic factor γ_0 is always greater than 1. Substituting (35) and (33) and (34), we find that (33) is satisfied whereas (34) is not. In other words, by choosing appropriate operating conditions so that the phase factor θ_0 falls between 0 and $\pi/2$, we may hope to use the same high power laser beam to pump and to amplify a free electron laser.

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APPLIED SCIENCES

BRIEFS

LASER OUTPUT STABILIZER--The Yancheng Electrooptic Instrument Plant and the Shanghai Institute of Measurement Technology have jointly developed a device that can greatly improve the stability cf the output power of a He-Ne laser. The device is called a LPS-II laser power stabilizer. The output power fluctuations of He-Ne lasers on the market are generally fairly large, about ± 5 percent. With the LPS-II stabilizer, the output water stability is improved by a factor of 100 and the fluctuation becomes less than ± 0.05 percent. The instrument has been tried out and 48 experts and professors from 32 units including the Chinese Academy of Sciences, industrial departments, local research institutes, and some universities and colleges participated in a live test and evaluation session organized by the Municipal Science Committee of Yancheng. The performance of the instrument was judged to be superior. The power stability capability of the instrument is achieved by electrooptic modulation. Today only a few industrially developed countries can produce this type of high performance power stabilizer. [Text] [Article by Ji Zhong [4764 6988]] [Shanghai ZHONGGUO JIGUANG [CHINESE JOURNAL OF LASERS] in Chinese Vol 13 No 2, 20 Feb 85 p 95] 9698/12947

CSO: 4008/80

SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

TOP NUCLEAR BOMB EXPERT'S SIMPLE LIFE PRAISED

HK290705 Hong Kong ZHONGGUO XINWEN SHE in Chinese 0713 GMT 27 Aug 86

[Report by ZHONGGUO XINWEN SHE reporters Li Chun [2621 2504] and Wang Jinchang [2769 6651 2490]; "'House, Children, and Car' of the Founding Father of Nuclear Bombs"]

[Text] Beijing, 27 Aug (ZHONGGUO XINWEN SHE)--It is difficult for certain cadres on the mainland to surmount the "three barriers." Very often, they have a fall and are criticized by the masses because of the problems of houses, children and cars.

Deng Jiaxian was the founding father of China's nuclear bombs. He performed a valuable service, and occupied a lofty position. How did he deal with the problem of "house, children and car?"

He Felt Satisfied Although His House Was Old

The whole Deng Jiaxian family lived in an old building located in the northwestern corner of Beijing. There were no complete sets of furniture in the house, although they were no longer rare in the houses of ordinary people. There were no high-grade "foreign goods" which were often seen in the apartments of senior cadres. Apart from several bookcases, what were most eye-catching in his house were a pair of sofas. Deng Jiaxian and his wife had one son and one daughter, and employed a maid. They only occupied three rooms. Deng Zhidian, the 32-year-old daughter of Deng Jiaxian, said: "We moved here five years ago. My father said that he was satisfied with the house."

Before moving to the house, Deng Jiaxian lived in an apartment with two bedrooms. Some decent furniture such as sofas, desk and so onwas hurriedly provided by the departments concerned when Deng Jiaxian planned to meet his good friend Dr. C.N. Yang in 1972.

Deng Jiaxian lived earlier in an apartment with only one bedroom. He shared a kitchen and toilet with other two families.

When a reporter came to Deng Jiaxian's apartment to interview him, he failed to find the Deng's house although he went around in a circle in the courtyard.

He eventually entered the best house in the courtyard. After making an inquiry, he found out that it was a kindergarten.

Deng Jiaxian never asked for a better house for himself, but he showed concern for the housing conditions of other research fellows. On 16 October 1984, the 20th anniversary of China exploding its first atomic bomb, Hu Qili came to the research institute where Deng Jiaxian worked. Deng briefed Hu on the housing conditions, saying that an associate research fellow lived in a house without windows. This matter arrested the attention of the CPC's highest leadership. Consequently, four new buildings were erected successively in the courtyard. Other people moved into the new houses, but Deng Jiaxian still lived in his old apartment. People could hardly believe that the host of this very common apartment was the meritorious founding father of China's nuclear bombs, and the hostess was lady Xu Luxi, elder daughter of the NPC Standing Committee Vice Chairman Xu Deheng, and professor at the Beijing Medical University.

He Loved His Children, but Never Spoiled Them

Both Deng Jiaxian and his wife were career-minded persons. They did not have much time to take care of their children. Once the "great cultural revolution" started, Deng Jiaxian's maid was driven out, and his wife was complained against. Since he was busy with his work, his son and daughter had to learn to cook when they were still very young. His daughter still remembered that when she prepared her first meal for herself, she used cold water to cook the noodles. As a result, the noodles became a paste.

In 1969, the 14-year-old daughter was sent to the production and construction corps in Nei Mongol. Deng Jiaxian might have transferred his daughter back to the city earlier because of his contributions to social relations. But he did not do so. His daughter was the last to return to the city among the children of resarch institute cadres.

Did this mean that Deng Jiaxian did not love his children? The answer is no. He regarded his daughter as a pearl in the palm. He could have once returned to Beijing by a plane for a good rest after the completion of a nuclear test. However, parental affection brought him to Uliang Suhai in Nei Mongol to visit his daughter. To do so, he had to take a train for several days and nights and walk more than 20 km.

His daughter was brought up during the "great cultural revolution," and only drifted along at school for several years. Deng Jiaxian and his wife regarded the work of increasing their daughter's cultural knowledge as a special task. Every time they received their daughter's letters, they always corrected the wrongly written characters and sentences in the letter. and then sent it back to her. When the daughter took part in the university entrance examination, they educated her so that she could enter the university by relying on his own capability. Her basic knowledge was poor. Deng Jiaxian took part in meetings during daytime. At night, he helped his daughter make up the lessons she missed. They worked till four or five o'clock in the morning. Some people said: "A member of the scientific council of the Chinese Academy of Sciences teaches junior secondary school physics. It is quite a job for Lao Deng."

With Regard to a Car, the Driver Said That "It Is Easy to Serve Him."

According to regulations, Deng Jiaxian could have a special car for himself. However, at ordinary times, he liked to go to work by bicycle. According to his wife, at one time when he was riding a bicycle, he thought of atomic bombs. Once he let his mind wander for a moment, he and the bicycle tumbled into a ditch.

Of course, to save time, Deng Jiaxian also took a private car. However, he never nitpicked. He was willing to take any car, whether it was a sedan, jeep, or truck. It was all right as long as he could arrive at the destination. The driver said: "Lao Deng is a kind-hearted person. It is easy to serve him." He once went to the airport sitting in the cab of a truck. Security guards at the airport interrogated him for a long time. We can hardly blame them, because no high-ranking official would go to the airport by truck. Was that not so?

Deng Jiaxian also took a cow-drawn carriage. In 1973, he went to Nei Mongol to visit his daughter. When he returned to Beijing, his daughter hired a cow-drawn carriage to take him to the station. Some people asked him what he had felt about it. He said humorously: "It is quite comfortable, and free enough."

Deng Jiaxian did not like to take the car specially reserved for him, even when he was seriously ill. On the eve of Spring Festival in 1985, Deng Jiaxian took a rest at home after undergoing a surgical operation. The doctor absolutely prohibited him from reading and working. Hiding the drainage tube in his duck's down jacket, he went to the library by bus in order to look up technical literature. Actually, if he intended to go out, a private car would be at his srvice, once he made a phone call. But Deng Jiaxian said: "It is very convenient to take a bus."

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DETERMINATION OF NON-HYDROCARBON CONTENTS IN LUBRICATING OILS BY FID-TLC METHOD

Dalian SEPU [CHINESE JOURNAL OF CHROMATOGRAPHY] in Chinese No 3, May 86
pp 146-148

[English abstract of article by Lin Leming [2651 2867 2494] and Zhang Lefeng [1728 2867 3488] of Dalian Institute of Chemical Physics, Academia Sinica]

[Text] A rapid method for quantitative determination of total non-hydrocarbon contents in lubricating oils was described. The sample is separated on a quartz rod coated with silica gel using n-hexane as the developing solvent. The separated bands are then detected by an on-line flame ionization detector. The quantitation is carried out by peak area normalization employing an integrator. The results were compared to those obtained by conventional method. (Paper received 19 Jun 85.)

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/6091
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PROPAGATION CHARACTERISTICS OF GUIDED MODES ON FIBER-CORE SPLICED SECTION AND APPLICATION TO MONOMODE FIBER DIRECTIONAL COUPLER

Shanghai GUANGXUE XUEBAO [ACTA OPTICA SINICA] in Chinese Vol 6, No 1, Jan 86 pp 42-48

[English abstract of article by Fang Xisheng [2455 6932 3932], Mao Zhongming [5403 0112 2494], and Li Binhong [7812 3453 3163] of the Department of Electronic Engineering, Shanghai Jiaotong University]

[Text] The first-order perturbation theory is used to analyze the propagation characteristics of guided modes on fiber-core spliced section. The results are applied to determine the theoretical coupling amount of monomode optical fiber directional coupler with strong transverse coupling by means of the mode excitation theory. Our theoretical results are in good agreement with the experimental measurements. (Paper received 17 Jun 85, finalized 7 Sep 85.)

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CLINICAL SIGNIFICANCE OF TEAR LYSOZYME ACTIVITY IN HERPES SIMPLEX KERATITIS

Beijing ZHONGHUA YANKE ZAZHI [CHINESE JOURNAL OF OPHTHALMOLOGY] in Chinese Vol 22, No 3, 12 May 86 pp 171-173

[English abstract of article by He Yulan [0149 3768 5695], Zhang Shujuan [1728 3219 1227], and Fu Hengtai [0265 1854 1132] of Wuhan Medical College]

[Text] Tear lysozyme activity in 74 cases of herpes simplex keratitis before treatment and after recovery was studied. It revealed that the enzyme content of tears during the active stage of herpes simplex virus infection was lower than that of normal eyes. The relationship between the amount of tear secretion and lysozyme content was studied in 44 patients. It was found that the lysozyme content was lower and the rate of tear secretion was higher as compared with normal eyes, while the resumption of normal tear flow after recovery was much sooner than the lysozyme content. This indicated that there was not a real negative correlation between the two, and the decrease of lysozyme activity probably resulted from damage to the lacrimal gland by the herpes simplex virus. Hence, determination of lysozyme activity of tears may be used as a means for immunological diagnosis, as well as an indicator for the necessity of continued treatment of the disease.

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FREE JEJUNAL GRAFTS FOR RECONSTRUCTION OF PHARYNX, CERVICAL ESOPHAGUS

Beijing ZHONGHUA ER-BI-YANHOUKE ZAZHI [CHINESE JOURNAL OF OTORHINOLARYNGOLOGY] in Chinese Vol 21, No 2, 10 Jun 86 pp 81-84, 156

[English abstract of article by Wang Tianduo [3769 1131 6995], Sun Yongen [1327 3057 1869], and Chen Ying [7115 3841] of Shandong Medical College Hospital, Jinan]

[Text] Reconstruction of the pharynx and cervical esophagus continues to pose a challenging problem to the surgeon. Over the last two years, the free jejunal graft with microvascular anastomoses has been used to reconstruct the pharyngoesophageal defect in 10 consecutive cases with only one absolute failure due to microscopic handicaps and a temporary pharyngocutaneous fistula. Eight operations were performed for reconstruction of pharyngoesophageal defect after an extensive excision of hypopharyngeal carcinoma, one for pharyngoesophageal defect due to cervical trauma in an accident, and another due to corrosive atresia. Seven of these cases had the unaffected larynx or normal part of the larynx preserved and reconstructed, the results were total restoration of laryngeal function in 4 cases and partial restoration in 3 cases.

The techniques of both pharyngoesophageal and laryngeal reconstructions are presented. In our experience this is a reliable, much safer and single staged procedure with much easier and much earlier rehabilitation as compared with other methods of reconstruction. (Paper received 26 Jan 86, finalized 23 Sep 85.)

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X-RAY DIAGNOSIS OF SOLITARY SEGMENTAL, LOBAR PULMONARY TUBERCULOSIS

Beijing ZHONGHUA FANGSHEXUE ZAZHI [CHINESE JOURNAL OF RADIOLOGY] in Chinese Vol 20, No 3, 10 Jun 86 pp 135-137, 26 of plates

[English abstract of article by Li Tieyi [2621 6993 0001] and Ji Jingling [0370 2529 3781] of Beijing Friendship Hospital, Radiation Department, Ba Yiqiu [4101 6654 4428] and Wang Yuewen [3769 6460 2429] of Beijing Anzhen Hospital]

[Text] This is a radiologic-pathologic correlative study of 52 cases of pulmonary tuberculosis, presenting roentgenologically as segmental or lobar shadow. Pathologically, caseous tuberculosis was the most frequent finding, proliferative lesions the next and fibro-cavernous tuberculosis was occasionally found. Coexistence of chronic inflammatory changes with tuberculous lesion constituted the pathologic basis of the segmental and lobar shadows on the chest films. Stenosis or occlusion of the segmental or lobar bronchus was an unusual finding whereas stenosis and ectasia of the 4th-5th divisions of the bronchial tree were frequently seen. Multiple nodules, masses or cavities were discernible in the background of segmental or lobar shadows and helpful for differentiation from lung cancer.

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